THE JUNE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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J. McKEEN CATTELL, Editor

WARE CATTELL, Associate Editor

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THE SCIENTIFIC MONTHLY

JUNE, 1936

SOME RELATIONS OF THE NEW HARMONY MOVEMENT TO THE HISTORY OF SCIENCE IN AMERICA

By Dr. C. A. BROWNE

SUPERVISOR OF CHEMICAL RESEARCH, BUREAU OF CHEMISTRY AND SOILS, U. S. DEPARTMENT OF AGRICULTURE

THE widening of the scientific frontiers in the English-speaking settlements of North America is indicated by a number of definite landmarks which offer to the historian convenient starting points from which to explore the intellectual development of various regions. The establishment of a laboratory in Boston by the younger Winthrop three centuries ago is one of these landmarks, for it was he who gave the first impetus to scientific studies in the English colonies. The founding of a laboratory by the exiled Priestley in 1794 at Northumberland, Pennsylvania, then upon the borders of the western wilderness, is another of these scientific outposts which helped to enlarge the intellectual boundaries of the young American republic. A third example was the establishment by Robert Owen in 1825 of a communistic colony at New Harmony, Indiana, from which center a group of eminent men set forth during the next half century to assist in the scientific development of the Middle West.

Robert Owen, the founder of English socialism, deserves the credit of having made the first and only actual experiment in America of applying the theories of communism to a society in which science occupied a leading position. This was not a new conception. Among the literary works of various epochs, which describe an ideal society of humankind, are several that picture the man of science as the proper helmsman of affairs. In Plato's "Republic," the earliest and greatest of these imaginative conceptions in which many of the social panaceas of later writers are anticipated, it will be recalled that the legislators of his ideal community must first have perfected themselves in the mathematical sciences, by which was meant the Pythagorean quadrivium of arithmetic, geometry, astronomy and music. These belonged to the ancient liberal arts, as contrasted with the so-called practical arts, such as agriculture, architecture, navigation and metallurgy, the study of which Plato held to be unworthy of serious attention. Yet Plato realized very clearly that his *οἰκισταί*, or legislators, must humanize their scientific knowledge by descending from their ivory towers and mingling with the common herd. "They must not be permitted," says Socrates in Plato's dialogue, "to remain in the upper world as philosophers do now but be made to descend among the prisoners in bondage and share their labors and honors whether these be more sordid or more worthy." But Glaucon asks, "Is it just

National Portrait Gallery, London

FIG. 1. ROBERT OWEN (1771–1858)

PORTRAIT BY W. H. BROOKE IN 1834. MEDALLION BY JULIAN LEVEROTTE.

to dishonor them and make them lead an inferior life when they could have a superior one?'' ''You forget,'' Socrates replied, ''the purpose of the law, which was not that one class of the community should fare happier than the rest but that all should be made happy alike.''

This ideal of bringing equal happiness to the members of a community through the agency of science was cherished again twenty centuries later than Plato by Sir Francis Bacon in his ''New Atlantis,'' where a bureau of investigators, working cooperatively, was supposed to increase the well-being of their fellowmen by means of their discoveries and inventions. Bacon for the first time stressed the importance to the community of training citizens in the neglected industrial arts, such as those of the farm, the kitchen and machine shop.

The practical application of some of these Utopian schemes did not begin to be seriously considered until after the outbreak of the American Revolution, which acted as a stimulus to the minds of social as well as of political reformers. Saint Simon (1760–1825) and Fourier (1772–1837) in France and Robert Owen (1771–1858) in England all attempted to found communistic societies and all with the same inevitable failure. Saint Simon advocated a new industrial state under the direction of men of science, a socialistic scheme which has had its latest repercussion in the recent flare-up of technocracy. Many young graduates of the École Polytechnique, afterwards famous as engineers, economists and practical business men, were attracted to the Saint Simon colony, in the Rue Monsigny of Paris, which supported itself for a brief period out of a common purse and then was dissolved.

These communistic experiments found their richest field for development in the United States, where over 50 different socialistic colonies were founded before 1850. The oldest of these, established by the Shakers at Watervliet, New Yor, in 1776, was of a strictly religious character, and it may be noted in passing that in its few remaining centers the self-supporting colonies of the Shakers have been the longest to survive.

Another of these sectarian communis-

tic groups was that of the Rappites, a company of pious German peasants from Württemberg, who, under their religious leader, George Rapp, settled first in 1804 near Zelienople, Pennsylvania, and then in 1815, desiring a more favorable situation, established a second colony in Indiana to which they gave the name of Harmony. Here this society of primitive Christians, or Harmonists, erected numerous log, frame, stone and brick buildings, among which were a large church, a granary, numerous residences, 6 large community houses and 8 or 10 small factories. Some 3,000 acres of land were laid out in farms with vineyards and orchards. This settlement in the wilderness was soon transformed by the industry of its inhabitants, about 1,000 in number, into a beautiful agricultural community, which became one of the early show places of the Middle West. To quote an early observer, "It would seem to the traveled visitor like some quaint German village, transported from the Neckar, or the Rhine, and set down in this western waste like an Aladdin's palace." After ten years of prosperity, during which the Rappite property was said to have increased in value to over $1,000,000, its leader, always restless for new adventures, decided to move back again to Pennsylvania, and the whole tract of Harmony with land, buildings and equipments was sold in 1825 to Robert Owen, as the site of a new communistic experiment, for less than $150,000.[1]

Robert Owen, the purchaser of Harmony, had ideas of social reform that were wholly unlike those held by its original founder. Instead of a religious autocracy, it was Owen's purpose to found a different type of community, a New Harmony, in which all the inhabitants would be people of superior intelligence and education, all striving amicably together toward his own ideals of high social attainment. Certainly, no

[1] With the proceeds of this sale Rapp purchased a large estate in Beaver County, Pennsylvania, eighteen miles below Pittsburgh on the Ohio River, and there his colony of obedient followers with renewed labor created another communistic settlement called Economy, which continued to exist with diminishing success until after the beginning of the present century, when decreasing numbers brought its activities to an end.

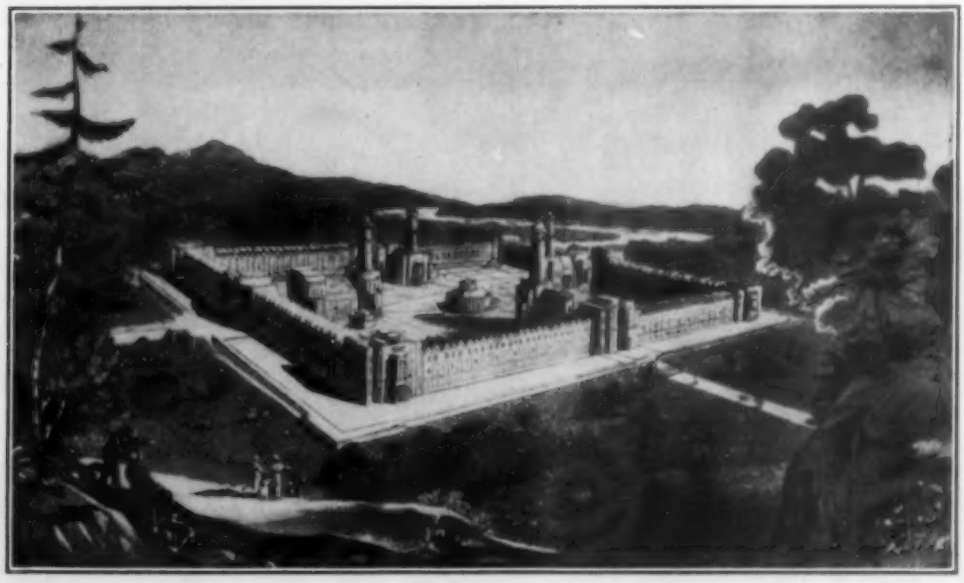

FIG. 2. ROBERT OWEN'S PROPOSED COMMUNITY VILLAGE
FROM AN OLD PRINT.

FIG. 3. WILLIAM MACLURE (1763–1840)
PORTRAIT IN AMERICAN JOURNAL OF SCIENCE, OCTOBER, 1844.

one was better qualified than Owen, in character, training and ability, to head such a movement. At a time when labor-saving machinery first began to be employed on an extensive scale, Owen by his high administrative and technical ability became at the early age of 19 the superintendent of a large cotton mill in Manchester and with such success that he soon made it one of the leading factories in Great Britain. Shortly after this he married the daughter of a wealthy manufacturer at New Lanark, Scotland, in whose factory he acquired by purchase a controlling share. As manager of this factory he took a most active philanthropic interest in improving the living conditions of the workmen of his mills. By the betterment of homes and of sanitation, by reducing the drudgery of labor, by encouraging habits of thrift and of temperance and by the establishment of model schools, he effected such an uplift in the character of the community that New Lanark was visited by royalty, social reformers and statesmen from all parts of Europe.

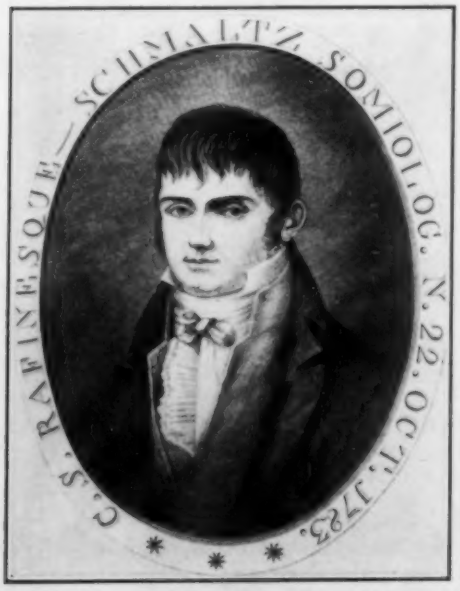

FIG. 4. CONSTANTINE SAMUEL RAFINESQUE (1783–1840)
FROM AN ENGRAVING IN RAFINESQUE'S "ANALYSE DE LA NATURE."

After the great business depression in Great Britain which followed the Napoleonic wars, Owen came to the conclusion that the competition of human labor with machinery was the great cause of the difficulty and that the only cure of existing evils was a reorganization of society in which machinery should be subordinated to man. For this purpose he advocated the establishment of self-supporting agricultural-industrial settlements of about 1,200 persons, each with from 1,000 to 1,500 acres of land. Each community was to be supervised by capable, scientifically trained overseers; complete facilities for public education were to be supplied, private ownership of property was to be abolished and the rewards of labor were to be shared in common. Having failed in his efforts to establish such settlements in Great Britain, he came to America, where at the opportune moment the community of the Rappites at Harmony, which seemed ideal for a first experiment, was offered for sale and purchased.

What Owen hoped to accomplish by his proposed regeneration of society was indicated in two memorable addresses which he delivered on February 25 and

March 7, 1825, in the Hall of the House of Representatives at Washington before the President, the Judges of the Supreme Court and both houses of Congress. The fame of Owen's New Lanark accomplishments had already spread to America and few reformers have ever been favored with a more distinguished audience. He exhibited a model of his community villages, in which the main building consisted of a hollow quadrangle, one thousand feet on a side, sections of which were marked out for schools and a university with lecture rooms, concert halls, laboratories and libraries. The material wants of the population were supplied by a community dining room and by dwelling apartments, well furnished and supplied with gas, water and other conveniences. He hoped, as the movement spread, to establish other similar villages, each independent yet all working together for the advancement of the common cause.

> Here it is [said Owen] in the heart of the United States, and almost in the center of its unequaled internal navigation, that Power which governs and directs the universe and every action of man has arranged circumstances which were far beyond my control, and permits me to commence a new empire of peace and goodwill to men, founded on other principles and leading to other practises than those of present or past, and which principles in due season, and in the allotted time, will lead to that state of virtue, intelligence, enjoyment, and happiness which it has been foretold by the sages of the past would at some time become the lot of the human race.

It is not our purpose to describe the progress and failure of Owen's communistic experiment, but only to regard the part played by certain scientists, who were attracted to the New Harmony movement, and to consider some of the influences which they exercised upon the cultural and industrial growth of the Middle West.

For the development of the educational and scientific part of his social program Owen enlisted the cooperation of a wealthy Philadelphia geologist, William Maclure (1763–1840), who like Owen was a whole-hearted philanthropist and a firm believer in the need of social reform, although he differed from Owen with regard to some of the methods by which this end was to be achieved.

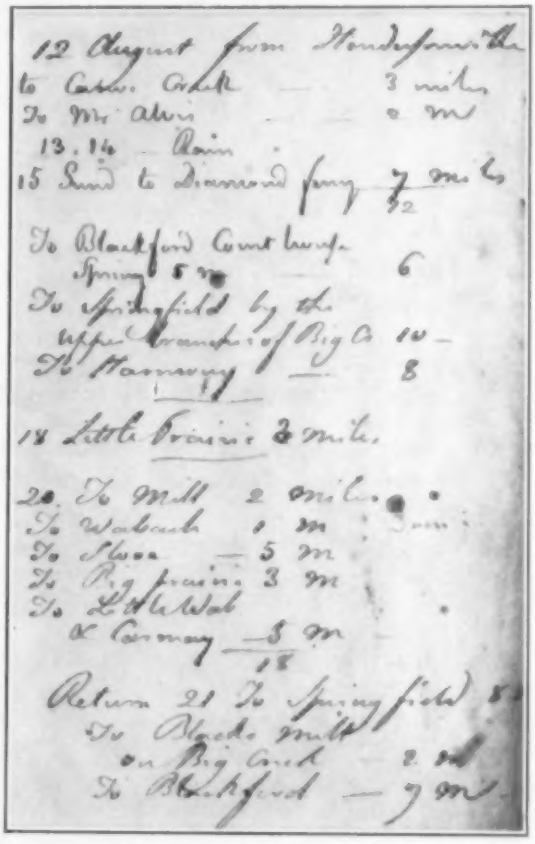

FIG. 5. RAFINESQUE'S ITINERARY OF HIS VISIT TO HARMONY IN AUGUST, 1818

FROM NOTEBOOK IN LIBRARY OF NATIONAL MUSEUM, WASHINGTON, D. C.

Maclure, who was born at Ayr, Scotland, engaged in business at the age of 33 in the United States, where he soon became one of its leading citizens. In 1803 he was sent to France on a diplomatic mission and during this period devoted his leisure to the study of geology, which he pursued energetically after his return to the United States in 1807. Unaided, he began the self-imposed task of making a geological survey of the United States.

He traversed on foot nearly every state in the Union, crossing and recrossing the Alleghenies some fifty times and mapping the regions which he visited. The results of this work were submitted to the American Philosophical Society and published in its Transactions for 1809 together with the first geological map of the United States. This work was greatly enlarged in 1817 in Maclure's "Observations on the Geology of the United States." These pioneer publications of Maclure have won for him the title of "The Father of American Geology."

It has been the lot of few Americans to exercise so strong an influence upon the lives of their scientific contemporaries as William Maclure. He took a prominent part in 1812 in founding the Philadelphia Academy of Natural Sciences, which included among its early members such distinguished scientists as the well-known chemist and geologist, Dr. Gerard Troost (1776–1850), and the eminent naturalist, Thomas Say (1787–1834), sometimes called "The Father of American Entomology," both of whom were Maclure's intimate friends. Troost was the first president of the Philadelphia Academy, holding office from 1812 to 1817, when he was succeeded by Maclure, who held the office for the next 23 years. Maclure was born a Scotchman, Troost a Hollander, Say an American, and to this group was soon added a fourth representative of another nation, the renowned French naturalist and traveler, Charles Alexandre Lesueur (1778–1846), whom Maclure in 1815, during one of his stays in Paris, persuaded to accompany him on a scientific expedition to the West Indies. Lesueur then continued with Maclure to America, where, after making a scientific pilgrimage through the North Atlantic States, the two friends settled in Philadelphia, at that time the center of American science. Lesueur was already well known in the United States and was quickly elected to the Philadelphia Academy of Natural Sciences and the American Philosophical Society, of which Maclure, Troost and Say were also members. These four men, of whom Maclure was the leading spirit, formed a group that cooperated closely for a number of years in making scientific surveys of the different states.

Maclure's interests in education and social reform were almost equal to his love for science. Having been attracted to New Lanark by Robert Owen's work upon improving the condition of the working classes he very naturally became interested in this reformer's plans for a socialistic experiment at New Harmony. Maclure supported the program of his friend with characteristic energy. He contributed to the venture not only his personal support and one hundred and fifty thousand dollars of his own money, but he secured also the participation in the enterprise of his scientific friends Troost, Say and Lesueur. A group of several of these and other lesser lights in the fields of science, education and social reform made up the famous "Boatload of Knowledge" which sailed down the Ohio River from Pittsburgh in January, 1826, and after encountering delays from ice and other causes reached New Harmony on the 26th of that month.

Several scientists had visited Harmony before the arrival of Maclure and his friends. The most noted of these was Constantine Samuel Rafinesque (1783–1840), a pioneer figure in the history of American science. Much uncertainty prevails about his career and there are many contradictions in his published biographies. He was born in Constantinople in 1783 of French-German parentage, and after a wandering boyhood, in which he acquired a love for natural science, he came to America in 1802. In 1805 he went back to Europe, where he spent ten years in Sicily in clerical and mercantile pursuits, continuing meanwhile his studies in botany and other

FIG. 6. NEW HARMONY DURING THE OWEN OCCUPATION
FROM AN OLD PRINT.

sciences. He returned in 1815 to the United States, where he spent the remainder of his life in teaching and other miscellaneous occupations, but most of all in making extensive scientific excursions to various parts of the country. He was one of the first to study the plants, fishes and shells of the Middle West. Unfortunately the eccentricities of this self-made naturalist have distracted attention from his contributions to botany and ichthyology. Long before Darwin he announced that new species and new genera were derived from previously existing forms. Rafinesque's desultory wanderings took him to Harmony as early as August, 1818, during Rapp's régime, his itinerary with dates being indicated in one of his note-books. In his "Life of Travels" (Philadelphia, 1836, p. 56) he wrote in 1835:

> I made an excursion to new Harmony on the Wabash, where dwelt the sect of Harmonists, and since famous by the vain efforts of Messrs. Owen and Maclure to establish communities. I saw there Dr. Miller who had a fine herbal and gave me some fine plants; we went together to herborize in the meadows.

It has been stated in some of the biographies of Rafinesque that he was associated for a time with the community established at New Harmony by Owen and Maclure,[2] but this statement rests

[2] One of the many conflicting statements in the various sketches of Rafinesque. Youmans in his "Pioneers of American Science" (p. 186) states that Rafinesque, following the course of the Ohio, explored for the first time the botany of the country and then came to Indiana where he was associated for a short time with the community then lately established by Owen and Maclure at New Harmony. Call also in his "Life and Writings of Rafinesque" (pp. 29–30) states that Rafinesque on his journey to the mouth of the Ohio "passed through New Harmony, Indiana, which was then one of the great scientific centers of the New World. In that quiet town on the Lower Wabash dwelt Say and Owen and Maclure and LeSueur. . . ." Actually Rafinesque (as shown by his "Life of Travels" and by his manuscript Notebook No. 18 in the library of the National Museum) made his trip along the Ohio and to Harmony in the summer of 1818, which was eight years previous to the arrival of Maclure and his scientific friends. Crawford in his excellent "New Harmony Movement" (p. 77) refers frequently to Rafinesque (whose name he constantly misspells) and commits the same errors as Youmans and Call. Many mistakes of this kind, one writer repeating another, have unfortunately crept into the biographies of early American scientists.

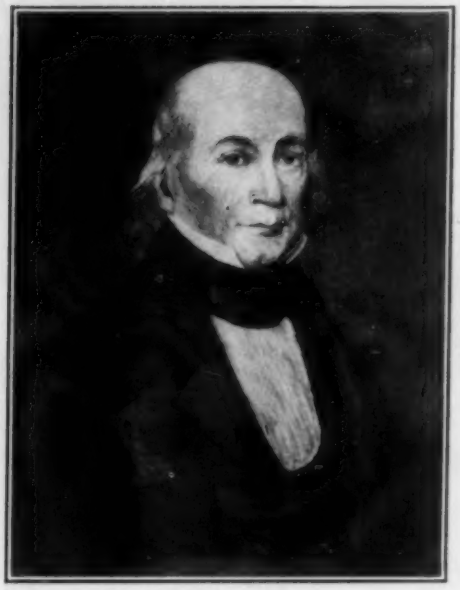

FIG. 7. GERARD TROOST (1776–1850)
REPRODUCED FROM A PAINTING IN THE HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

upon mistaken evidence. Rafinesque had previously made the acquaintance of some of the New Harmony scientists, but as for joining them he states explicitly in his "Life of Travels" (p. 79) that while he had "some intention to join Mr. Maclure at New Harmony" it was well that he did not do so "since his views and fine College have been abortive." The peregrinations of this restless naturalist took him finally to Philadelphia, where, after living obscurely in great poverty, he died in 1840 at the age of fifty-six.

Other distinguished members of the New Harmony scientific group were the two youngest sons of Robert Owen—David Dale Owen (1807–1860) and Richard Owen (1809–1890). They were educated, like their older brothers, Robert Dale Owen and William Owen, in the school of Emmanuel von Fellenburg at Hoffwyl, Switzerland, where they pursued chemical studies which were afterwards continued under the celebrated Scotch chemist, Dr. Andrew Ure, in Glasgow. They sailed for America in November, 1827, and reached New Harmony in January, 1828, too late, however, to assist their father in staying the failure of his socialistic experiments.

Among the famous visitors to New Harmony in the early period was Bernhard, Duke of Saxe-Weimar Eisenach, who arrived there during a tour of the United States in April, 1826, only a few months after the coming of Maclure and his "Boatload of Knowledge." The Duke's "Travels through North America," published at Philadelphia in 1828, throws interesting sidelights (Vol. II, pp. 106–123) upon the activities of some of the scientists in New Harmony. A few of his observations about the community are quoted.

> I renewed acquaintance here with Mr. Say, a distinguished naturalist from Philadelphia; . . . unfortunately he had found himself embarrassed in his fortune, and was obliged to come here as a friend of Mr. Maclure. The gentleman appeared quite comical in the costume of the society . . . with his hands covered with hard lumps and blisters, occasioned by the unusual labor he was obliged to undertake in the garden. [p. 113.]

> I had an ample conversation with Mr. Owen relative to his system and his expectations. He looks forward to nothing else than to remodel the world entirely; to root out all crime; to abolish punishment; to create similar views and similar wants, and in this manner to abolish all dissension and warfare. When his system of education shall be brought into connection with the great progress made by mechanics and which is daily increasing, every man can then, as he thought, provide his simpler necessities for himself, and trade would cease entirely! I expressed a doubt of the practicability of his system in Europe, and even in the United States. He was too unalterably convinced of the results to admit the slightest room for doubt. It grieved me to see that Mr. Owen should allow himself to be so infatuated by his passion for universal improvement as to believe and to say that he is about to reform the whole world, and yet that almost every member of his society, with whom I have conversed apart, acknowledged that he was deceived in his expectations and expressed their opinion that Mr. Owen had commenced on too grand a scale and had admitted too many members, without the requisite selection. [p. 115.]

> I passed the evening with the amiable Mr. Maclure and Madame Fretageot, and became

acquainted through them with a French artist, Mr. Lesueur, . . . as also a Dutch physician from Herzogenbusch, Dr. Troost, an eminent naturalist. Both are members of the community and had just arrived from a scientific pedestrian tour of Illinois and the southern part of Missouri, where they have examined the iron and particularly the lead mine works, as well as the peculiarities of the different mountains. Mr. Lesueur has besides discovered several species of fish, as yet undescribed. He was there too early in the season to catch many snakes. Both gentlemen had together collected thirteen chests of natural curiosities, which are expected here immediately. [p. 122.]

In these few extracts from the observations of the Duke Bernhard we catch a vivid glimpse of the scientific and social atmosphere of New Harmony as well as of the undercurrent of doubts concerning the outcome of Owen's socialistic experiment. Matters in fact were rapidly approaching a crisis. The presence in the community of a crowd of adventurers, speculators and loafers, who preyed upon the industry of those who were willing to play the rules of the game, proved too severe a strain upon human nature. Efforts were made to purge the society of undesirable members and plans were changed, all too frequently, to secure a greater degree of collaboration. The population, however, was too dissimilar in sentiment and ideals for cooperative action. Dissensions long brewing between Owen and Maclure (the inevitable result of the contact of two such strong-minded personalities) terminated in an open quarrel over debts and property rights, the very issue which communism is supposed to prevent. The social experiment initiated in New Harmony was accordingly abandoned by Owen, although the possibility of establishing other communistic centers under more favorable auspices was cherished by this idealist until his death thirty years later.

Following the end of Owen's communistic experiment came also the failure of Maclure's educational system of self-supporting industrial schools for children. With the final and permanent withdrawal of these two influential promoters the town of New Harmony went over to the established system of private ownership. The only reminders now of its two communistic periods under Rapp and Owen are some thirty old buildings of antiquarian interest and a library and museum of historical books and mementoes.

FIG. 8. THOMAS SAY (1787–1834)
FROM A LITHOGRAPH IN THE HALL OF THE ACADEMY OF SCIENCES, PHILADELPHIA.

The influences emanating from New Harmony as a scientific and educational center did not cease, however, with the retirement of Owen and Maclure but continued with increasing effect for many decades to come. Of the four Philadelphia scientists, Maclure, Troost, Lesueur and Say, who originally went to New Harmony, Troost was the first to withdraw, removing in 1827 to Tennessee, where he accepted in 1828 the professorship of chemistry, geology and mineralogy in the University of Nashville, an office which he filled with great distinction until his death in 1850. As state geologist he published many reports upon the iron, coal and other mineral resources of Tennessee as well as numerous scientific papers upon the fossils and other

geological remains of Tennessee, Missouri and other neighboring states.

Maclure, the geologist, the oldest member of the group, was the next to leave. He departed late in 1827 for Mexico to recover his health, taking with him his friend, Thomas Say, who returned to New Harmony the following year. Maclure died in 1840 while formulating plans for the endowment of workmen's institutes and libraries. Eighty thousand dollars under the provisions of his will were distributed in Indiana and Illinois for the founding of libraries. Although these collections have now mostly disappeared, they served in their time as the nuclei of many of the existing free public libraries of the Middle West. The present magnificent New Harmony library survives as a memorial to the philanthropic founder of American geology.

Thomas Say, the youngest member of the group, was the first to pass away. He continued to reside at New Harmony until his death in 1834 at the early age of forty-seven. Say is best known for his "American Entomology," the third and last volume of which was published in 1828 during his residence in New Harmony. His "American Conchology or Descriptions of the shells of North America" was printed at the School Press of New Harmony in 1830. The work is dedicated to his friend, William Maclure, and some of its drawings were made by his other friend, C. A. Lesueur. Other plates in this volume were made by Say's wife, Mrs. Lucy Sistare Say. The associations connected with this book make it unique in the history of American science.

FIG. 9. THOMAS SAY'S TOMB AT NEW HARMONY

Charles Lesueur, the fourth member of the Philadelphia group of scientists, also resided for a time at New Harmony after the termination of the communistic experiment, the companionship of his friend Thomas Say being a strong inducement for remaining longer upon the frontier. During this interval he explored some of the mounds of southern Indiana and wrote numerous articles upon the fishes and mollusks of the Middle West, supporting himself meanwhile by his skill in painting and sketching. In 1832 Lesueur and Say were visited

by the distinguished European explorer, Prince Maximilian of Neuwied, who with his scientific staff remained in New Harmony from October 19, 1832, to March 16, 1833. In June, 1834, Prince Maximilian passed through New Harmony again on his return eastward and Lesueur accompanied him as far as Vincennes. The Prince's American observations are contained in his two large volumes, "Reise in das innere Nord Amerika in den Jahren 1832 bis 1834," of which chapter VIII is devoted to New Harmony and the surrounding region.[3]

The death of Say in 1834 severed the last link which bound Lesueur to New Harmony, and three years later he returned to France, where he ended his days in 1846 as the curator of a natural history museum in Havre.

With the passing of these original founders we come now to the later period of science at New Harmony, which began with the work of David Dale Owen, who, following his arrival in 1828, continued to increase his chemical knowledge by means of home experiments. In 1831 he journeyed to England to perfect himself further in chemistry and geology and then after returning to the United States took a course at the Ohio Medical College in Cincinnati from which he graduated in 1837. He was appointed state geologist of Indiana in 1838 and, having made New Harmony his permanent home, entered at once upon the work which for the next twenty-three years was to be his sole occupation. After completing his preliminary survey of Indiana, during which he made unassisted his own field observations and performed his own chemical analyses in his New Harmony laboratory, Owen was requested by the U. S. General Land Office to make an extensive survey of eleven thousand square miles of the Northwest Territory in what is now a part of the states of Wisconsin and Iowa. In 1847 Owen was appointed United States

[3] Plate 2 of the Atlas of this work consists of a fine engraving of New Harmony as it appeared a century ago.

FIG. 10. CHARLES ALEXANDRE LESUEUR (1778–1846)
FROM A PAINTING IN THE HALL OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

geologist to conduct a survey of the Chippewa Land District, a work which was later expanded so as to include more of the Northwest Territory. The results were published in 1852 in his "Report of a Geological Survey of Wisconsin, Iowa and Minnesota and incidentally of a Portion of Nebraska Territory." The head-

FIG. 11. DAVID DALE OWEN (1807–1860)

quarters occupied by the Geological Survey at New Harmony was the old stone and brick fort or granary, built in 1815 by the Rappites, which is still standing. In this building were housed the large mineral collections made by William Maclure and his colleagues, as well as those gathered by Owen and his coworkers in their extensive surveys of the states of the Middle West. In 1856 this immense mineral collection was divided, a part of it going to the newly completed Smithsonian Institution[4] in Washington,

FIG. 12. OLD RAPPITE FORT OR GRANARY, NEW HARMONY

HEADQUARTERS OF UNITED STATES GEOLOGICAL SURVEY UNDER DAVID DALE OWEN (1847–1852).

another part to the Indiana State University at Bloomington and a third portion to the American Museum of Natural History in New York.

Following his pioneer work as United States geologist, David Owen conducted geological surveys for the states of Kentucky and Arkansas. The great influence of his work upon geological survey operations in Missouri has been stressed by Mr. Arthur Winslow in an article upon geological surveys in that state. It is thus seen that starting from New Harmony as a center David Owen traversed in his geological work nearly all the states of the Middle West. The arduous labor connected with these surveys eventually undermined his constitution and his active useful career was brought to an end on November 13, 1860.

David Owen trained in his laboratory a large number of young assistants who afterwards became distinguished in geological work. Among the noted men of science who were associated with him at various times may be mentioned his brother, Colonel Richard Owen (1809–1890), who succeeded him as state geologist of Indiana; Professor E. T. Cox, the third successor in this office; Colonel Charles Whittelsey, the veteran Ohio geologist; B. F. Shumard, of the Missouri Geological Survey and afterwards state geologist of Texas; F. B. Meek, the well-known paleontologist; Dr. Elderhorst, who wrote a treatise on the blow-pipe; Dr. Robert Peter, the well-known Kentucky chemist; Professor Leo Lesquereux, the noted fossil botanist; Professor A. H. Worthen, the state geologist of Illinois; and many others whose names might here be mentioned.

New Harmony was much frequented by scientific visitors during the life of David Dale Owen. Dr. George Engelmann, one of the founders of the St. Louis Academy of Sciences, rode on horseback to New Harmony in February, 1840, but missed seeing the distinguished company of scientists whom he expected to meet there. Another visitor was Sir Charles Lyell, the famous Scotch geologist, who in his second tour of the United States in 1845–46 came from New Orleans by boat to Mount Vernon, Indiana, and proceeded thence by stage

[4] It is worthy of note that the bill for applying the neglected James Smithson bequest to the founding of the Smithsonian Institution was introduced in Congress by Representative Robert Dale Owen, of Indiana, the oldest brother of David Dale Owen, on December 14, 1845, and was passed the following year. The striking architectural features of the Smithsonian Building with its brown stone castellated towers have been attributed to the joint plans of Robert and David Owen.

to New Harmony. Of his visit there he relates:

> We spent several days very agreeably at New Harmony, where we were most hospitably entertained by Dr. and Mrs. David Dale Owen. . . . Some large buildings, in the German style of architecture, stand conspicuous and were erected by Rapp: but the communities founded by him, and afterwards by Robert Owen of Lanark, have disappeared, the principal edifice being now appropriated as a public museum, in which I found a good geological collection, both fossils and minerals, made during the State survey, and I was glad to learn that by an act of the Indiana Legislature, with a view of encouraging science, this building is exempt from taxation. Lectures on chemistry and geology are given here in the winter. Many families of superior intelligence, English, Swiss and German, have settled in the place, and there is a marked simplicity in their manner of living which reminded us of Germany. . . . Say, the eminent conchologist, who died at the age of forty-seven, formerly resided at New Harmony and recently Prince Maximilian of Neuwied and the naturalists, who accompanied him, passed a winter here. We found also, among the residents, a brother of William Maclure, the geologist, who placed his excellent library and carriage at our disposal. He lends his books freely among the citizens, and they are much read. We were glad to hear many recent publications, some of the most expensively illustrated works, discussed and criticized in society here.[5]

With this pleasing narrative by the great Scotch geologist of the scientific and social activities of New Harmony as they existed ninety years ago we must bring our account of some of its relations to the history of science in America to a close. The New Harmony scientific movement, first inaugurated by Rafinesque in his pioneer exploration of 1818, then brilliantly pursued by Maclure, Troost, Say and Lesueur in 1826, and afterwards continued with such marked success by David Dale Owen until his death in 1860, may be said to have reached its terminus with the death of Richard Owen, who passed away in his eighty-first year at New Harmony on March 24, 1890. He was the last survivor of the brilliant family of sons of Robert Owen and, as professor of natural science in the Indiana State University from 1864 to 1879, did much to stimulate a love for science among the students who came under his instruction.

[5] "A Second Visit to the United States of North America," by Sir Charles Lyell, Vol. II, London, 1849, pp. 270–2.

FIG. 13. SIR CHARLES LYELL

It was a unique phenomenon that a pioneer settlement founded by uneducated German peasants should have become so quickly a great cultural center of broad cosmopolitan character, where

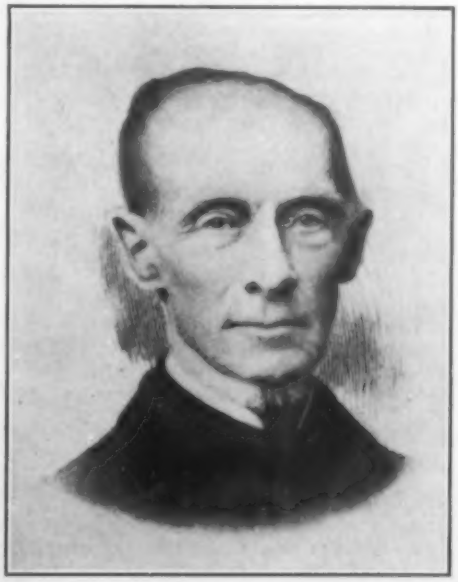

FIG. 14. RICHARD OWEN

not only American but English, Scotch, French, Dutch, Swiss and German scientists made their homes or their headquarters for various periods of time. It may be said of Robert Owen and William Maclure that while their socialistic experiment met with a speedy failure, they builded better than they knew. They blazed the way for those who dared to follow, and the work which they inaugurated contributed enormously to the cultural, scientific and industrial development of the Central States of our republic.

Although somewhat outside the scope of the present paper, it may perhaps be permitted in conclusion to devote a few words to a subject that is very pertinent to the New Harmony experiment, namely —the fitness of scientists to become the leaders in the legislative affairs of a community or a state or a nation. The question, as we have seen, dates back to the time of Plato, and it is widely discussed even now, especially in the scientific circles of England. Most generally it is the professional politicians who control the destinies of nations, and it is everywhere conceded that they have made a sad havoc of affairs, both national and international. But would congresses or cabinets of scientists have done any better? Professor P. M. S. Blackett, in his chapter on "The Frustration of Science,"[6] in the recent collaborative book of the same title, gives a very positive answer to this question.

There are some, he writes, who "conclude that the scientist should come out of his laboratory and turn his gifts of honest inquiry and objective judgment to help to put right the mess left by the politician. Such views are held quite widely, and not only by scientists. Of course, it is perfectly clear that any such hope is doomed to disappointment. Scientists, if in the position of politicians, would act like politicians."

[6] "The Frustration of Science," London, 1935, p. 133.

We are not prepared to accept Professor Blackett's decision as final, although the very imperfect experiment at New Harmony, so far as it went, seems to justify the view that hope in the scientist as the sole savior of the commonwealth "is doomed to disappointment." Certainly, no one was better qualified than William Maclure, either as scientist or business man, to manage the affairs of a community, but the human material with which he had to work was so refractory that he had to give up the attempt. This, however, should not deter scientists, as a class, from taking a more active part than they have in the past, in the management of public affairs. The examples of Franklin in America, of Playfair in England and of Berthelot in France demonstrate that scientists can fill public offices with credit and distinction. What is needed in the present age is a greater representation of scientists in our legislative chambers, and perhaps the best way of accomplishing this is to humanize our sciences so that the public at large will appreciate more fully what science has done and is doing for the welfare of society. "All our science lacks a human side," wrote Emerson, and scientists might attain to that high position in the commonwealth, accorded them by the Utopian writers, provided more of them withdrew, as Plato suggested, from their academic retirement and helped to solve some of the intricate problems in that most difficult, yet most important, of all sciences—the science of human relations.

Although the communistic phases of the particular program of reform, initiated by Owen and Maclure, can be dismissed as unworkable, the value of such small-scale social experiments, as they so bravely undertook, should be recognized. Present emergencies should call forth on the part of all scientists a manifestation of the same courage and philanthropic spirit as were displayed by Owen and Maclure in their efforts to

cure the social ills of a century ago. Failure undoubtedly will follow failure and yet, in view of the recent stimulating address by Dr. George Sarton upon "The History of Science and the Problems of To-day," we are hopeful enough to believe that there will come eventually a fulfilment of the prediction of Robert Owen that such efforts, "in due season and in the allotted time, will lead to that state of virtue, intelligence, enjoyment, and happiness which, it has been foretold by the sages of the past, would at some time become the lot of the human race."

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* Permission has been granted by D. Appleton-Century Company, Inc., to reproduce Figures 2, 6, 9, 12, 14 from Lockwood's "New Harmony Movement."

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† Permission has been granted by D. Appleton-Century Company, Inc., to reproduce Figures 4, 7, 8, 10, 11 from Youmans's "Pioneers of Science in America."

IS THE UNIVERSE RUNNING DOWN?[1]

By Dr. W. F. G. SWANN
DIRECTOR, BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE

WHEN the American Philosophical Society did me the honor of inviting me to deliver the Penrose Memorial Lecture, I was told that I was to speak upon "The Second Law of Thermodynamics"; and, on inquiry, I found that I was also expected to make it intelligible to those members of the society and their friends who are not mathematicians or physicists. On learning this, I bethought me of the medieval custom of trial by ordeal in which the culprit could only win freedom by performing some painful and impossible act. I began to wonder what sin I had committed, who might be my heartless enemy who was thirsting for my blood and in what unpleasant form he might be hoping to take it if I failed. Then, some element of mercy for me seemed to have penetrated the hearts of my judges; or, perhaps, was it mercy only for the audience, to spare them the horrible spectacle of my torments during the ordeal? It was suggested that the title be changed to "Is the Universe Running Down?" The change has been made; but you will get the same speech in spite of that.

If I should be asked to give a brief illustration of what, in its usual interpretation, the second law of thermodynamics means to the world of inanimate matter; and if, in order to bring it home to your consciousness a little more vividly, I should be allowed to extend it beyond the scope of its legitimate application, but perhaps within the scope of its spirit, then to our universe, with its molecules and atoms of dead matter, with its worlds, its stars and its galaxies rich in structure and in principles of control, I should add the world of animate beings, with all its intricate laws of government and of social structure. Standing beside me I should vision a cold and supercilious oracle who, in his statements to me, symbolized what, for this combination of animate and inanimate universes, would be the analogue of what the second law of thermodynamics would have to say for the inanimate universe alone. Let me cite, in the form of a dream, my supposed conversation with this oracle who guards within his consciousness the laws by which the universe is governed.

In my dream I saw much sadness around me; and I demanded of the oracle, "Can not the world be made better and richer than it is?"

"No," said the oracle, "it is bound for the dogs."

"But," said I, "may not a revolution occur which will improve the lot of those poor people whom I see yonder, and the lot of humanity in general?"

"No," said the oracle, "a revolution might improve, temporarily, the lot of the people you speak of, but it would destroy civilization somewhere else to such an extent that the world, or the universe as a whole, would be worse off than it was before. Even the temporary improvement in the people in whom you are interested would be but a passing phase, and their ultimate fate would be, if anything, hastened by their temporary good fortune."

"But," said I, "can matters never improve?"

"No," said the oracle, "they can only get worse in the long run—a house can fall down, but it can never build itself up again."

[1] The Penrose Memorial Lecture for 1935.

"But to pursue your own analogy about the house," said I, "might not yon house in falling down fall upon that factory over there, and, by hitting one of the machines, knock into place a certain bolt which I happen to know was always out of place, and which has so far prevented the machine from working. If that machine were set working, might it not build another house more beautiful and possessed of more intricate structure than that which was destroyed?"

"Ah! my friend," replied the oracle, "there might have been a universe in which such a thing could happen, but in our universe, governed by the laws which I have written upon a scroll in my pocket, I can tell you that such a thing can never happen; or, at any rate, if it did happen, it would happen with a degree of rarity such as to render the thought of its occurrence of no significance. But," the oracle continued, "before we can continue this conversation with profit, we must pause and come to a little better agreement as to what it is we are talking about. You stated that the second house which was brought into existence by the fall of the first might be more beautiful than the first. Before I can talk with you, we must have some measure of structure or beauty. Now I, the oracle, have a measure of structure; and in terms of my measure, the net structure in the universe would be less after the first house had fallen down."

"But, my dear Oracle," I interposed, "your measure of structure may be a very foolish one; and, in terms of my human intuitions, the actual structural content and richness of the universe may increase while in terms of your measure it diminishes."

"To that I agree," replied the oracle. "But the significant thing is this: in terms of my measure of structure, everything that happens in the universe tends to decrease the structure. You and your fellow humans may disagree with me that the structure is really decreasing; but my continual decrease of structure leads to an end-point. I can tell you what that end-point will be, and even you and your fellow humans will agree that the end-point which I vision is the limit of chaos. I, the oracle, say that we are moving towards chaos continually. You may not agree with me as regards the 'continually,' because you may not agree with my measure of structure; but call my measure what you like—call it a figment of the oracle's imagination, if you will—provided only that you accept the doctrines embodied in the laws of the universe which I have in my pocket, you will have to conclude that the changes of the universe are towards an end-point in which you yourself will admit that all structure has vanished. If you accept the doctrines to which I have referred, we may not agree as to the way in which we are going to the dogs, but we shall both have to agree that to the dogs we finally go."

"And what," I demanded, "is this final state of the dogs to which you refer?"

"It is one," he answered, "in which all men shall be equal. There will be no kings, no presidents, no government. All men will be exactly alike. There will be no criminals and no very good men. Nobody will have any ideas, and it will be impossible for anybody to do anything which he has not done before. There will be nothing that any one can do that every other can not do. Nobody will have any ambitions or regrets."

"Well," said I to the oracle, "at least we shall be safe, secure and stable."

"Yes," said the oracle, "you will be very stable—you will be dead; for in this chaos, as I see it, your very life, energy and potentialities for all action will be shared with so many things which now live not at all—with every grain of sand on the sea shore—that the amount which

will fall to the lot of any one of you will be small indeed."[2]

And then, in my despair, I implored the oracle to tell me whether, consistent with holding to the doctrines contained in the manuscript in his pocket which he seemed to value so much, there might not be *some* way in which the chaos of which he spoke might grow once more to order.

"Come," said he with a malicious laugh, "I will show you the only way in which what you wish can be done." And he took me into a desert where there was nothing but barrenness and sand. "Let us wait a while," he said. And as we waited a storm arose, and the sand was blown hither and thither. When the storm was spent, I saw before me a little pile of sand which the storm had blown there.

"Look at that pile of sand," said the oracle. "Do you think it very beautiful?"

"No," I replied, "it is just a pile of sand."

"Let us wait for another storm," said the oracle.

And we waited. Again the wind blew and the sand was scattered. When all was quiet once more, I saw before me another mound of sand. "What have you there?" said the oracle.

"I have a mound of sand," said I.

"Do you think it very beautiful?" asked the oracle.

"No," I replied, "it, also, is only a mound of sand."

"But," urged the oracle, "is it not of a shape different from the last?" I agreed that it was.

"Then let us wait for another storm," said the oracle.

"But," I protested, "what are we trying to do?"

"We are waiting," answered the oracle, "until, by accident, the storm will some day blow the sand into the form of a cathedral, and by accident blow from afar such ingredients as mixed with the rain shall produce the cement which by accident may fall in such places as are necessary to cement the cathedral together and make a permanent structure."

"But," I cried, "such a thing is impossible."

"No," the oracle said, "not impossible, but (and he became inexpressibly cynical) highly improbable."

And, as the oracle saw me meditating in sadness, he said: "Come, my friend, I will tell you why all this is so. Before the sand and dust which made this desert were here, they formed the parts of beautiful rocks, and, for all I know, cities and buildings. In this form they were part of a rich and beautiful structure. Why that structure existed, I do not know; but this I do know—that the number of ways in which the grains of sand and dust can be arranged into beautiful structures is infinitesimally small compared with the number of ways in which they can be arranged to produce no structure at all. Now the principles which I have in my pocket tell me that while the laws of nature do not object to the existence of beautiful structures if formed, they do not conspire to produce them to the exclusion of others. They have no preference; and when they get a chance to operate on a structure and produce another, they give equal opportunity to all structures, the beautiful and the barren. When they first operate to change a structure they do not necessarily produce complete chaos at once; but, little by little, they work in that direction, and always waiting in the distance of time are those structureless forms outnumbering immeasurably all those with structure. These swarms of barren forms await their share in what

[2] The technical reader will here pardon the invocation of a sort of principle of conservation of life which I have invoked into my analogy for purposes of illustration, a principle, of course, intended to typify the conservation of energy in the inanimate world.

nature has to give them. They await their turns to exist. Each of them awaits in expectation for its little life. And, when nature has bowed to their wishes, her chance to find a way back to order is infinitesimal. She has left but the order of disorder. Change she may indeed produce, but the new thing she creates has but an infinitesimal chance of having any more form than that which it replaced."

And now we must say good-bye to our oracle. His purpose has been to give us at the start of this lecture, and I fear well into the heart of it, a faint preview of the kind of story which it is our task to tell. We must return to the realities of inanimate matter exclusively and speak in language appropriate to the things which compose it. Before making the transition, however, I should like to show a simple experiment to illustrate the last remarks of our oracle.[3]

On the screen is a mechanical slide composed of red beads and colorless beads. The red beads are at the bottom and the colorless beads are at the top. For this reason the slide has a kind of structure. I will rotate the slide a few times. You will observe that the beads are now more mixed up. I will continue the rotation and now, as you will observe, the red and colorless beads are fairly evenly distributed. If I rotate the slide a few more times, you will not doubt but that the beads will then occupy positions entirely different from those which they occupy now. Yet, I suppose you would be very surprised if in that new arrangement we found all the red beads once more at the bottom and the colorless ones at the top. And yet, why should you be surprised, for I may as well tell you that that particular arrangement is as likely as any other one —the present one, for example? You are surprised because, intuitively, you have sensed in this case the point which the oracle was trying to bring out. The number of ways in which the beads may be rearranged to look very much as they look now is enormously large compared with the number of ways in which they can be arranged with all the red beads at the bottom and the colorless beads at the top, in spite of the fact that the number of ways of producing different arrangements of that kind by interchanging the red beads among themselves, and the colorless beads among themselves, is very large. There is always a *chance* that when I rotate the slide a few times more I shall find all the red beads at the bottom and all the colorless ones at the top, but the chance is infinitesimally small. You may be interested in knowing what it is in the present instance. The slide contains 70 red beads and 70 colorless beads. I have calculated that if I go on mixing them and then examining the result, I shall have to go through the operation on the average about—and here I have no name for the number of times because it has 140 zeros after it—before realizing a case where all the red beads are once more at the bottom and all the colorless beads are at the top. It took me but few mixings to create disorder out of order, but to create order from disorder requires untold mixings. Wide and many are the roads which lead from order to chaos; but narrow and few are the paths from chaos to order, and few there be who find one.

The second law of thermodynamics had its origin in the study of heat. It was preceded by what is known as the first law of thermodynamics which is frequently regarded as an extension of the principle of the conservation of energy to those processes in nature which involve the production or utilization of heat. Those members of my audience who are specialists in physics or allied fields will not require that I give them a definition of the meaning of kinetic

[3] The nature of the experiment here shown will be sufficiently obvious from the text.

and potential energy, and they will understand and forgive me, if, for the benefit of the others, I speak rather naïvely about these concepts where the naïvetés are more or less irrelevant, even though I speak with sophistication in other parts of my discourse where the matters concerned are significant. It will suffice then to say that a body, or a machine, or contraption or assemblage of contraptions possesses energy if it possesses the power to impart motion to other bodies. It may possess energy in virtue of its own motion—kinetic energy as we call it—for then by impact with other bodies it may impart motion to them. It may also possess energy on account of its state, as is the case with a coiled spring which, though quiescent, shows when released that it possesses very much power to communicate motion to other bodies. The spring possesses potential energy. In the general case, any system taken at random possesses both of these kinds of energy—kinetic and potential. When the physicist has sensed in the crude form new concepts such as kinetic and potential energy, he proceeds as quickly as possible to invent some "yard stick," in terms of which he can make measurements of them, just as a golfer proceeds to measure the efficiency of different players by measuring for them something which he calls a "handicap." Now in terms of the measurements which the physicist had invented for kinetic and potential energy, it turned out that most of the simple processes of nature went on in such a way that if we considered the system as a whole, its potential energy might change into kinetic energy or vice versa, but the sum of the two always remained the same. The total energy was conserved. An example is to be found in a mass tied to the center of a horizontal piece of elastic. If the mass is pulled to the right, in the direction of the length of the elastic, and if it is then released, it will vibrate back and forth across its mid-point. At the instant when the mass is at its extreme right, and is just about to reverse its direction of motion, its velocity is zero; and, it has no kinetic energy, although at this instant the elastic is stretched to its maximum degree, and possesses much potential energy. On the other hand, when the mass is passing through its mid-position, the elastic is unstretched, and so possesses no potential energy; but the mass is now moving at its fastest speed and possesses much kinetic energy. In the intermediate positions there is a mixture of kinetic and potential energies, but in the example quoted the sum of the two remains constantly the same. At least this would be so if there were no friction. But alas! as you well know, there is friction, and you know that, as a practical fact, the mass would not go on vibrating forever. The sum of the kinetic and potential energies—the total energy of the system—mass and elastic—would diminish with time. Now, it is possible for you to trace in a reasonable manner the loss of some of this energy, for the air is moved by the motion of the mass. But if you perform the experiment in a vacuum, you will still find that the motion of the mass will die down in time. You will attribute this fact, and quite correctly, to the friction in the elastic itself. But then, I begin to wonder whether the elastic has anything to show for this loss of energy which it has somehow or other demanded and collected in virtue of its friction. If I look at it at the end of the experiment, it will look just as it did before. If I examine it sufficiently carefully, however, I shall find that it has been slightly warmed. We say that heat has been produced in it by the friction. Now, one of the outstanding advances of the last century was made when it was realized that whenever energy, in the more obvious forms of observable kinetic and potential

energy, appeared to vanish, heat was produced somewhere as a result; and, moreover, it was possible to derive a method for measuring this heat, independent of the way in which it was produced, and such that when measured in this manner the heat produced was the exact equivalent of the energy which appeared to have been lost. Before this time, heat had been thought of as a kind of substance, a fluid which could be forced into or out of matter, and which was itself conserved and unconvertible into anything else. Now, however, the mind began to sense this apparently mysterious thing "heat" as really a thing of no mystery. It itself was merely a form of energy, and was, in fact, in large part nothing more than the kinetic energies of the individual molecules and atoms. When a system appeared to lose energy and so get hot, there was no real loss of energy. The energy of the big things of the system, the wheels and springs and masses, was simply transferred in part to the little things, the atoms and molecules, where it existed in the very definite form of their kinetic energy, for the most part, but in a form more difficult to get hold of and use than was the form in which it existed in the wheels of the machinery.

And so we started to look longingly at all the energy residing in apparently useless form in the atom and molecules. Could we not get it back again into the wheels of the machinery? It was not lost. There it was in the molecular motions. But must it exist forever in idleness with no more purpose than to make the molecules dance about? Think what a wonderful thing it would be if we could only get all that energy back into service. At present, when we run a train from Philadelphia to Chicago, we burn up about sixty tons of coal. When the train has arrived at Chicago, it has sensibly the same potential energy as it had in Philadelphia, since Chicago is at approximately the same altitude as Philadelphia. Even though the train has scaled a mountain on the way, it has descended again by the time it has arrived at Chicago. It had no kinetic energy just before it started, and it has none when it is brought to rest in Chicago. What has become of all the energy provided by burning the sixty tons of coal? In the first instance, some of it went to boil the water in the boilers. The steam pressure made the engine run, and some of the energy went into that process. A large portion of it went simply to heat the condenser of the steam engine. But even the part that went to run the engine finally became converted into heat in the friction associated with running the train, in the operation of the brakes, and so forth. In fact, practically all the energy supplied by the sixty tons of coal finally went into that particular form of energy which is called heat—into molecular motion and the like. If only we could collect it in some way and make it function again, we could run the train back to Philadelphia without using any more coal. In fact, if we could do this kind of thing, we could make our trains and much of our machinery run forever with but one initial supply of energy. There would be no violation of the principle of the conservation of energy. No energy has evaporated into nothingness as a result of the train's going to Chicago. If this kind of thing could happen, most of our transportational and mechanical operations would involve nothing more than the continual transference of energy from one form to another and back again with the accompanying happy state of affairs for ourselves that we got where we wanted to go and did what we wanted to do without payment of anything. Now, our experience gives us the suspicion that we can not do this kind of thing, and that something is wrong with any assumption to the effect that we can. But what is

wrong? The procedure does not violate the conservation of energy. It does not "cost anything" in the long run, in the form of disappearance of energy, to do this kind of thing. If I should inquire of nature as to why I can not do this thing which I should so much like to do, nature would probably answer me thus: "My laws are more restrictive than the conservation of energy. They require that conservation of energy shall be obeyed, but they also require other things. Just because you keep your energy bank book balanced that does not give you the power to do anything else you please."

"But how," I demand of nature, "am I to know what things of this kind are impossible?"

And nature says, "If you could see all the detailed actions which are taking place in my realm, you would see for yourself which things are forbidden. There would, in fact, be no need for forbidding. These things could just not happen. To attempt to see the matter in this way would be too complicated. If I were to attempt to tell you all of the individual things which would fail if you tried them, the tale would be too long, and you would not see much connection between the parts. However, I find that by making one decree, I can settle the matter for you. There is just one thing which I tell you you can never do. I know that I need say no more, for I know that, without violating that decree, you would never be able to do any of the thousand-and-one things you want to do, and I don't want you to do."

That one decree is the second law of thermodynamics. It places a restriction upon the ways in which work can be obtained from heat. It looks as though the second law of thermodynamics was invented in the Garden of Eden, when the Deity said to Adam, "In the sweat of thy face shalt thou eat bread." The example which I have already given—the impossible process of collecting all the heat generated by friction, etc., and converting it back to work—is a rather complicated illustration of a process which could be seen to be impossible by means of the second law of thermodynamics, and I only cited it on account of the spectacularness of its nature. It is not easy to state, in non-technical terms, just what the second law of thermodynamics is, but I shall try to illustrate the essentials.

In the first place, it is necessary for us to heed the schoolmaster's warning to all beginners in physics concerning the necessity of a careful distinction between temperature and heat. Speaking crudely, temperature is a measure of the degree of hotness of a substance. Now a cup of boiling water and a barrel of boiling water are equally hot; but, it obviously took more heat to raise the barrel of water to the boiling point than was necessary for the cup. I think I need say no more than that to recall to you the distinction between temperature and heat. Physically, this heat is nothing more than the energy of the ultimate individual entities of matter's structure, such as the molecules of the heated body, and our problem concerns how we are to be able to get it out of the heated body and make it do something. If we say we can never make this molecular kinetic energy do any useful work we are wrong, because a steam engine works by making use of the molecular energy of the hot steam. But if we say we can always use molecular energy for useful purposes, we are wrong; for, if we could, there should be nothing to prevent us from draining all the molecular energy out of the earth by cooling it to absolute zero, and then using it to run all our machinery. It would finally go back to the earth again in the form of molecular energy when, as a result of the friction in the machines, it had become degraded back to the molecular form. Then when

it had gone back into the earth we could proceed to use it again. The earth would be as good as the widow's cruse of oil of biblical fame.

Now when we come to ferret out just how and how not, when and when not, we are able to utilize molecular energy, we find that the whole question boils down to this: We can get the molecular energy out of matter in a practically usable way[4] only provided that we utilize at least two pieces of matter, one colder than the other. Then we must take heat, *i.e.*, molecular energy, from the hotter body, but we must not use all of it; we must pay a tax to the body of lower temperature. The laws of nature make the inanimate world like a conglomeration of philanthropists of varying degrees of wealth (symbolized by the temperature in the case of the inanimate things), and characterized by the fact that you can get a donation from one of these philanthropists for a desired purpose, provided only that you promise to give some of the donation to one of the poorer philanthropists. If you try to get money from the philanthropists in any other way, nature conspires to block your operations so that you can only do it once.[5] Every transaction is thus accompanied by a kind of sales tax; and this tax is terribly high. In the case of an ordinary steam engine, it amounts to more than 70 per cent. of the energy transaction involved. In the inanimate world, nature seems to like to utilize every activity for the purpose of helping the poor (symbolized by low temperature bodies) at the expense of the rich.

Speaking crudely, we may say that nature likes to equalize temperatures. Everybody knows that nature likes to equalize the temperatures when two bodies of different temperature are placed in contact. We should be very surprised if, under such conditions, the hot body became hotter and the cold one colder. But the spirit of the second law of thermodynamics is to the effect that, even in the more subtle processes where heat is transferred between bodies through the medium of work, nature likes to equalize temperatures as a result. Nature is like human beings. Human beings will permit sections of society to exist in different states of prosperity, but whenever she gets a chance in the form of a revolution, things so arrange themselves that the revolution reduces the disparity.[6] And so, nature will allow things to exist at different temperatures, provided that we take precautions to guard them from loss of heat by such processes as conduction; but, if we give nature a chance by starting anything, she will take advantage of it for the purpose of making the temperatures of the various things more nearly equal than they were before. The second law of thermodynamics, which symbolizes the foregoing principle, is thus the most politically radical doctrine in the universe.

The second law of thermodynamics expresses itself by denying the possibility of processes which do not conform to a certain criterion. It tells us what we can not do. Our laurels earned by obedience to it are like the laurels of the saints, who appear to have been canonized for the most part for what they avoided doing. But it so happens that a sufficiently comprehensive statement of

[4] I use here the designation "practically usable way" as a symbol of processes in which, in the operations incidental to the utilization of the energy, the machine involved repeats continually a cyclical process.

[5] I am here citing an analogue to the case where, for example, in a system all at one temperature initially, one could obtain work by allowing a gas to expand and so cool, but could not get the system back to its original state with a net accomplishment of work as a result, without utilizing the principle of transference of some heat from a warm body to a colder one.

[6] However, this analogy must not be pressed too far; for human beings seem to possess the power to recreate the disparity again.

what can not be done sometimes implies a statement of what can be done. If we knew the complete mechanism of the universe in all its parts, the second law of thermodynamics would not, of course, add any information; but, when we do not know all about the processes, the second law can tell us something. Thus we know that water expands when it freezes; and, knowing this, we can deduce from the second law of thermodynamics that the melting temperature of ice must be lowered by subjecting the ice to a pressure. This result is, of course, well known as an experimental fact. When we squeeze a piece of ice, it melts, because its temperature, which was low enough to keep it frozen before the pressure was applied, is no longer low enough after the application of the pressure. However, apart from our experimental knowledge of the fact itself, it is by no means an *obvious* thing that the melting temperature of ice should be lowered by pressure. The opposite is true for wax. Without delving into the realms of atomic structure, we know far too little to see "just why" the melting point of the ice is lowered. The second law of thermodynamics relieves us of the necessity of knowing all about the process. It tells us the answer without our going through the complication of seeing "just why." It may appear a very trivial piece of information that the second law has given us in this case. Yet, if the melting temperature of ice had been raised by pressure; or, even if it had been lowered, but by an amount different from that predicted by the requirements of the second law of thermodynamics, I could take all the heat out of everything around and make myself a millionaire. It would then be possible, in principle at any rate, to construct a machine which would continually perform work by simply cooling everything that there was to cool. We could drink the heat out of our poor old earth, out of the sea, and everywhere, and could go on running our trains and street cars with the energy thus made available. Just as now we use the earth's coal, so, under these conditions, we could use its heat. I do not refer to the use we could make of its internal heat, owing to the fact that the inside is hotter than the outside. We could use that part quite in harmony with the second law of thermodynamics, the only difficulty being in getting at it. I refer to the heat which, under the postulated conditions, we could obtain from the earth even though all of it were at the temperature of its exterior. We could obtain a good deal of power in this way. We could obtain about ten thousand million horse power for ten thousand million years. Moreover, when we had used the heat once, and it had gone back to the earth, we could use it again. But, while the second law does not tell us the details of all nature's workings, she tells us that we can not do any such thing as this. Only by equalizing the temperature differences around us can we devise practical schemes for converting heat to work. As long as we have bodies at *different* temperatures, we can convert heat to work. If we have only a few hot bodies, we shall soon exhaust our possibilities in this respect, because the hot bodies will become cooled and the cold bodies warmed by the operation of the very processes we use for converting the heat into work; and, when all differences of temperature have been wiped out, our possibilities come to an end.

The second law of thermodynamics rests upon the fact that all the consequences which it has predicted have been found to be true experimentally. It is like a race-horse tipster. It lives on the truth of its former predictions. It will only continue to live so long as its predictions continue to be in harmony with the facts; but it has made such a lot of true predictions in the past that we have

become accustomed to trust whatever it predicts when it predicts new consequences.

When one has formulated the law of gravitation for the motion of the heavenly bodies, it is possible to see in terms of it just why the planets behave as they do; and, during the last century, a good deal of thought was expended in an effort to see just why the second law of thermodynamics should hold—to see just what detailed story of the atomic forces of nature could be responsible for this tendency of matter to seek always to equalize temperatures, not merely by the processes of conduction of heat from the hot to the cold, but by other processes as well. The mathematician got busy and showed that this tendency to equalize temperatures was the same story, but in other words, as one which would say that nature is trying to progress in such a way as continuously to make a certain quantity greater. That quantity was called the entropy. It was possible for the mathematician to calculate quite definitely in terms of such things as the pressure, temperature, and so forth, of any particular part of the universe, what the value of that mysterious quantity, the entropy, was, which had such a desire to become as great as possible. The quantity itself was not a very familiar looking thing in terms of our ordinary concepts. It was not like mass or velocity, or any one of the things we meditate upon in our every-day thinking. It was a sort of combination of these familiar things. But after all, we have no reason to be alarmed at that. For, if you should make, in precise terms, a definition of a golfer's handicap, it would seem a rather complicated and abstruse thing to one who was not a golfer. Nevertheless, it is a very useful thing in golf. It is the thing which has useful properties in telling part of the story of the activities of the golfer; and so this entropy was the thing which had the useful properties in the science of thermodynamics. Nevertheless, having admitted this new concept into the subject, the mathematicians and physicists still continued to try to see, by an appeal to the more detailed mechanisms of atomic processes, just why this quantity should have such an ambition to grow and grow in the universe. And the more the mathematicians thought about the matter, the more perplexing the problem became; for, without pinning oneself too closely to any particular form of atom theory or fundamental laws, it seemed that almost any of them would have no more desire to persuade the entropy to increase than to decrease. A simple illustration of the processes in this connection may be obtained by considering the case of the solar system; and it will be a little better if we complicate our ideas a little by laying a little more stress upon the features concerned with the mutual perturbations of the planets than is done, so that we picture a situation in which the orbits of the planets do not repeat themselves with perfect regularity, but on account of their mutual perturbations, go on changing a little from year to year. As a matter of fact, we do not have to apologize for this extension of ideas. It is really no extension at all. It is actually happening, only to a very small degree. The smallness need not worry us, we have plenty of time to watch it, and let us go on watching it. Suppose now at some instant we should suddenly reverse the velocity of every individual body, planet, satellite, comet. Then, the laws of gravitation tell us a remarkable thing. They tell us that the whole history of the solar system will redescribe itself backwards, and in every detail. In fact, as far as the laws of astronomy are concerned there is no more reason why the system should go through a sequence of changes in one direction in time than that it should go through exactly the

same sequence in the reverse direction. The feature which is responsible for this state of affairs is, moreover, not particularly characteristic of the law of gravitation, but is characteristic of almost any set of laws of the kind we had been accustomed to think of in physics, no matter how complex the laws might be. Thus if, with laws of this type, we should vision a set of molecules composing various pieces of matter which were originally at different temperatures and have shared their heat so as to be now at the same temperature, and if then we should suddenly reverse the velocities of all the molecules; or, more precisely, every part of the molecules which has motion, it would seem as though everything, every state and event, should take place backwards in time, so that the bodies would proceed to acquire a difference in temperature. The kettle which was put on the fire to get hot at the expense of the fire becoming cooled, would, under these conditions, become cooled once more and heat up the fire.

An equally remarkable situation is encountered by considering the well-known case of a box divided into two halves by a partition. The right-hand side is evacuated and the left-hand side is filled with air. I now punch a small hole in the partition and the gas rushes through the hole until both halves are equally filled, and then the process stops. You are content—I am surprised. One of the differences between the physicist and the layman is that the layman is apt to be confused and surprised when the physicist is happy and contented with a situation, while the physicist is surprised and worried when the layman sees no earthly reason why he should be worried at all. And so I invoke my professional prerogative of being surprised that the gas always shows a tendency to equalize itself, and never shows a tendency which would result in the equalized gas getting restless to the extent of causing all the molecules on one side to leave that side and go into the other side, like rats leaving a ship. Of course, I have no right to be surprised that there is no demon who takes it into his head to reverse the motions of all the molecules now and again. What surprises me is that none of these reverse processes seem to exist spontaneously in nature, since the ordinary physical laws we have been accustomed to think of, even with a wide range of possible extensions in their form, have no preference against these reverse processes. And so the physicist has been compelled to admit to himself that, within all reason, these reverse processes can occur, and do occur; and yet he has to see a way in which they do not result as a practical fact in what would appear to be absurd results in the light of our experience. The key to the dilemma seemed to reside in the principles exemplified in the example which I showed earlier concerning the red and colorless beads. I started with the colorless beads on the top and the red beads below. On shaking them, I have gotten them into their present state of more or less equal distribution. If I shake them again, I shall be surprised if they do not look very much as they are now. Yet, every time I shake them I redistribute them, and give them one of the many opportunities which exist for their taking another distribution. Among those many opportunities is that one which takes them back to the state where the colorless beads were on top and the red ones below, but I shall be very surprised if they find that pattern. Every time I shake them, I change them, but, of all the opportunities which exist for them on such a change, so many take them to another state in which they are mixed up in a manner which, as regards its essential characteristics, is the same as that in which they now are, that the chance of their getting out of this state is infinitesimal. The beads are some-

thing like a man in a maze. He tries once to get out and fails. He tries again and fails. There are so many ways in which he can try and yet stay more or less where he is, and only one way in which he can get out, that he may remain in the maze a long time. Yet, there is no difficulty in getting into the maze. He does that on the first try, just as I mixed up the beads from a state of order to one of chaos without any difficulty at all.

And so, our difficulty in the matter of bodies which are at the same temperature not starting to diverge in temperature, is not to be solved by denying the possibility that they can do so, but by emphasizing the fact that when they make any change, the path they take is so enormously more likely to bring them to another state in which their temperatures are still the same than it is likely to bring them to any other state, that the chances of the realization of such other states is infinitesimal. It may be of interest to cite once more the case of the box with the partition, and to emphasize that the reason that the molecules distribute themselves throughout the two halves equally, rather than in one half of the box only, is bound up with the relative chances of occurrence of the two states. I must not attempt here to define my terms too precisely, since to do so would require a long digression for that purpose. It will be sufficient for the spirit of the matter to quote a statement cited by Sir Arthur Eddington which I shall paraphrase slightly, to the following effect: "Suppose that a number of monkeys are provided with typewriters and are allowed to play upon the keys as suits their fancy, turning out pages and pages until they have finally typed as many letters as there are letters in all the books in the British Museum. Let us then bind these writings of the monkeys into volumes. The chance that the letters will fall in the necessary order actually to reproduce word for word all the books in the British Museum is enormously greater than the chance that in the room in which you are sitting, for example, all the molecules will be found at some instant in one half of the room. The same principles would apply in lesser degree to a number of people seated in a large auditorium. The number of ways in which we can redistribute them on the chairs is much larger if they occupy the whole auditorium, than if they crowd themselves into half of it. Yet, I surmise that if there is a conjurer on the platform, they will all be found in the front half if they can get in. May there not be something like this in nature. When I spoke of there being many more paths from order to chaos than from chaos to order, I only intended to imply that such *might* be the case. It must certainly have been so in the case of the beads. What is certain is that there are enormously more states of chaos than there are states of order. There are enormously more ways in which the red and colorless beads can be arranged and rearranged and still stay mixed than there are ways in which they can be arranged and rearranged with all the colorless ones at the top and the red ones at the bottom; but the number of ways in which a system can be rearranged so as to remain sensibly the same as it was before is not necessarily indicative of the number of opportunities for it to make the rearrangements. If you should distribute all the dollar bills equally among the people in this country, the number of ways in which by interchange of dollar bills you could keep the distribution of wealth undisturbed is enormously great compared with the number of ways in which the dollar bills could be redistributed among different people so as to retain the relative distribution of wealth which we now have, in spite of the fact that we do not in our different distributions limit ourselves to

the cases where the *same* people are always wealthy. Yet it does not result as a consequence that we find equal distribution of wealth. The reason is that the laws which govern the flow of wealth tend to favor the accumulation of wealth unequally. Indeed, the fact that if we started with an equal distribution of wealth we should soon realize an unequal distribution is very closely analogous to a situation which we would have if bodies originally at a uniform temperature made distribution of their heat in such a way that some of the bodies became very hot at the expense of others being very cold.'"[7]

And so it was necessary for the physicist to commune with himself as to whether he could gather from the laws of nature, as he knew them, enough to tell him that the probability of the existence of a state as measured by the number of ways in which it could be realized was really a measure of the chance that the system would get into that state. It is rather difficult to say in reasonably non-technical terms just how the physicist set about this, but I will do my best. Suppose, as an analogy, I imagine our solar system changed about. It is possible, in imagination, to take the elements which composed it, the comets and the planets, and set them off in other orbits, with the earth in the orbit of Halley's comet, for example, or in some possible orbit which does not happen to be occupied by any known comet; and to make corresponding modifications in the rôles of all the other bodies. I can have the moon going around the sun on its own account in a more independent manner than as the servant of the earth. It is to be supposed, however, that in this new arrangement of the heavenly bodies, I adjust matters so that the total energy is the same as before. The new solar system which we produce may be called a new possible state of the entities contained in the old one. I may perform this transformation again, and again, and in fact a very large number of times, and then contemplate this spectacle of millions of solar systems all the same as ours in the sense that they contain the same entities, but all in different states. I shall suppose that in this galaxy of states which I picture, I include a representation of every possible state which the elements of our solar system could exist in, subject only to all the states having the same energy. And now, if I am interested in discussing the kind of way in which the solar system changes spontaneously with time when in any one of its states, I have the whole picture before me, in the sense that there is a representative of every state which can exist. Like Joshua, I have commanded time to stand still so that I may look at the solar system for an instant; but I have improved on Joshua, for I have demanded that at one and the same time I may have a look at the solar system in each of the configurations which in its whole history it can occupy. Having had this vision, let time start moving on once more. Each of our pictures of the solar system will proceed to change. The way in which each changes will be determined by the laws of nature as applied to the particular state from which the change is to progress. Some of our pictures may represent very stable states, in the sense that the laws of nature are content to leave them very much as they are. Others may suffer rapid and drastic changes directly the laws of nature operate on them. In my original map-

[7] For the interest of those who are specialists in the subject, I would emphasize that we must not place too much weight upon a supposed difference between the human and the physical problem founded upon the different capabilities of the individuals who acquire different amounts of wealth; for, if we wish, we can invoke the different kinds of coordinates of the physical system as symbolic of different kinds of individuals. Then as to whether or not one class will be favored will depend upon the laws of the subject.

ping out of these various states I gave a sort of impartial picture of all possible states. Of course I could not draw an infinite number of pictures, but I drew in my mind's eye one state, then another which was a little different from that, then another a little different from the second, and so on, so that there was no particular state of the universe that any one could bring me such that I could not find something like it in my chart. I am like a criminologist who has drawn a lot of pictures of finger-prints differing successively from one another, and so complete that there is no criminal whom you can bring me for whom, on finger-printing him, I can not find one of the previously drawn records which is something like the actual finger-print obtained. And so, when I drew all my pictures of the solar system, I gave a fair representation to all possible states of it. But the laws of nature may not like my drawings. Nature may say, "Truly that picture number one thousand and three, which you have drawn, is a possible state of the solar system, but the solar system could never exist for any length of time in a state anything like it. I should drive it out of that state as fast as I could, and into one more pleasing to me."

"Well," I say to nature, "take these pictures which I have drawn as starting points, develop each of them as you will, and let me have another look later."

Then it may be that, as time progresses, nature will change certain of the pictures very little, while taking others, which she likes less, she may gradually modify them in such a manner that, when she has gotten things as she wants them, these states will be represented very poorly, all the original representatives of them having been guided out of them into states which nature likes better, and with no compensation in the form of a return from other quarters. If now I have another look at my modified pictures, I may feel aggrieved. I say to nature, "You have made a nice mess of my work of art. What have you done with ninety-nine per cent. of my nice pictures of the solar system? Why have you left only these few?"

"I didn't like the others," says nature, "they were terrible, so I changed them."

"But," I say to nature, "this is very unfortunate, for I want to tell you something. In nearly all those pictures which you have destroyed, there was one central idea, an idea common to all. This idea does not exist in the very specialized pictures which you have left me. As a matter of fact, such an overwhelming proportion of my former pictures had in them that central idea, that property, that I have told everybody that the idea was a fundamental consequence of the workings of your laws, in the sense that whatever state the solar system may be in, that property will almost certainly be found in it."[8]

"Well," says nature, "perhaps it was because I didn't like the property that I ruled it out. What kind of property was it anyway?"

"A very peaceable property," I reply, "one which does not disturb anything or produce any crises in the universe."

"Ah! a back-boneless property," says nature, "a fine property to work for in nature, a fine property to make a universe out of. No wonder I didn't like it."

Now let us point out the significance of our analogy. Just as I asked you to vision all possible states of the solar system in one picture, so the mathematical physicist has visioned in one picture all states of an assemblage of molecules and of distribution of energy among them. All but an insignificant propor-

[8] I need hardly remind the physicist that the property here spoken of is to be taken as the analogue of one of the properties (such as equipartition of energy) of the so-called normal state.

tion of the states were ones in which the molecules had gotten down to a sort of share-equally-for-all basis, of the kind I have symbolized earlier in this address, a condition in which the average energy of a group of oxygen molecules was the same as the average energy of a group of hydrogen molecules; a condition, moreover, in which things other than molecules had come to eat out of the trough. Each individual wave length of the spectrum of the heat waves of the radiant heat passing back and forth in an enclosure claimed an equal share of the energy. There are an infinite number of different wave-lengths, so that if the distribution of energy were made in this way among the molecules and among the waves there would be only an infinitesimal amount for each of the claimants. All but an infinitesimal proportion of the states of the molecules and waves associated with them possessed this lugubrious property. So the mathematical physicists appealed to the laws of nature to see whether they would not do something such as, for purposes of description, I have visioned them as doing in the hypothetical case of the pictures of the solar system. Would not the laws of nature exercise a sort of presidential veto against the overwhelming majority of representatives of the universe which were voting for chaos, and for the least amount of differentiation between the individuals, the least specialization in properties? Now, the truth was that the physicist did not know what the laws of nature really are, but he was able to show that, provided only that they were of what is known as a dynamical type, they would render no assistance, but rather would just let the universe run to the dogs.[9] I fear I can not pause to explain just what is meant by a dynamical system. The physicists will know, and, I fear, the others would get but little enlightment if I told them. It will suffice to say that the dynamical type of law is one which, while it permits a wide modification in detail, possesses certain characteristics much beloved of classical physicists. Provided then that the laws of nature were of this dynamical type, the changes which the laws permitted would allow the universe to wander indiscriminately through all the possible pictures which we could draw of it,[10] so that the chance of the universe finding itself in one of those barren states to which I referred would be, on this basis, overwhelmingly large.[11] As the physicists meditated upon this state of affairs in relation to the story of the older framing of the laws of thermodynamics, it turned out that that tendency of the apparently mysterious quantity, entropy, to become greater and greater, which tendency was the symbol of what the second law had to say—that tendency could be nothing more than an expression of the tendency of systems to seek states of greater and greater probability. In fact, the mathematicians were able to show how, by assuming that the entropy was nothing more than an expression

[9] I refer here, of course, to the implications of the famous theorem of Liouville, which is founded upon laws of the Hamiltonian type.

[10] A few reservations must here be made for the benefit of the technical reader. The argument given excludes the case of re-entrant paths, such as are associated with dynamically degenerate systems. The general implication seems to be to the effect that a sufficiently fine-grained consideration of the system would show that, in the last analysis, there were no absolutely re-entrant paths and that, given time enough, the system would occupy all states consistent with the conservation of energy.

[11] Even should we accept the implications here suggested, nevertheless, as I remarked twenty years ago in a discussion of this matter in the *London and Dublin Philosophical Magazine*, there is no reason for wonderment at our present condition. We may admit the extreme improbability of the existence of the universe in its present state, but we must remember that it is only during the very rare periods of existence of this improbable universe that there will be found in it those highly improbable beings like ourselves to study it.

of the probability, a very elegant story of the meaning of the science of thermodynamics could be built up. Entropy, as it had existed in the mind formerly, was simply a quantity which the physicist had accidentally stumbled upon and found how to measure because it had an important property. It now appeared that the physicist, when measuring entropy, was really measuring probability in spite of the fact that what he actually measured did not look like probability. The physicist was like a little boy looking at the log attached to the stern of a ship. What he sees is a pointer going round and round. What that pointer really measures is the speed of the ship.

Now the physicist likes to generalize. The idea which presented itself in examining the ways of molecules and atoms and heat radiation gave rise to the thought that all energy, even the energy of the internal structure of the atoms, and of the very electrons themselves, might be seeking to free itself from the bonds of structure and join the ranks of chaos where little pieces of it would have so much greater freedom to jog about from one thing to another without doing anything in particular. If we accept this idea as a principle—a starting point in itself—then there is of course nothing further to be said. From the practical standpoint the question at issue is "How far are we *compelled* to accept the idea?"

Now the failure of the laws of nature to cooperate in preventing the universe from going to the dogs is exactly in line with the requirements of the second law of thermodynamics over that region of experimentation which has given rise to the law. It must be regarded as an experimental fact that nature seeks to go to the dogs in some of her activities; and, any reversing principles which we contemplate introducing into the laws of nature must not deny the privilege of nature to go to the dogs when she wants to. How far can we go without running contrary to the demands of experiment and experience?

It is true that, in the sense in which the mathematician counts different states of a system, there is an overwhelmingly infinite number of states which are representative of the state of dead chaos which I have pictured earlier; but this, of itself, does not necessarily mean that there is an overwhelmingly large practical chance of the universe seeking an ultimate permanent existence in these states. We must not assume that some sort of infinitely improbable and complicated law of nature would be necessary to guide the universe out of chaos. Because there is so much water in the sea wherein I can drown, that does not necessitate an infinitely complicated ship to take me across the ocean. It is true that the law structure of the old classical dynamics provided no succor in the matter, but as every physicist now agrees, that law structure does not hold for atomic processes.

It is readily possible to invent a law structure which will avoid the unpleasantness of ultimate dead chaos. This is not the time to demonstrate the fact; but that there is nothing mysterious in it may be seen by citing again the analogy which I have already cited, concerned with the distribution of dollar bills among the world's populace. Apart from the laws governing the flow of business and of dollar bills, practically the same mathematical principles are available to show that the state of equal distribution of these bills among all the people is overwhelmingly the most probable distribution in the ultimate state, as are available to show that, in the case of the physical world, an ultimate state of chaos, of a universe run down, is overwhelmingly probable. As I have implied, the enormous odds in favor of equal distribution of the dollar bills have practical significance only in the absence

of controlling laws; and it is not hard to understand that the laws of economics and of man's behavior may be such as to prevent such a distribution of wealth.

If I should cite a still simpler example, but one in which the laws concerned are those governing animals, I would say that, if I should bring several million flies into this room, I could prove that the distribution of the flies which, by mathematical calculation, was the most probable distribution would be one in which each cubic foot of space contained practically the same number of flies. Yet, you all know what would happen if I put a bowl of honey on the table. I know that some of my physicist friends will point out that the classical theory has a way of taking account of things like the honey, and that the potential energy, in its control of the unequal distribution of molecular atmospheric density with altitude, for example, provides an illustration. To this I agree, but hasten to point out that this latter fact itself is just an illustration of how the cooperation of law structure with the numerical operation of counting states does produce an ultimate result in which the law structure can show its mark.

I feel, therefore, that, in our present rather incomplete knowledge of the laws of atomic processes, we can not say that the laws demand chaos as the ultimate fate of the universe. On the other hand, there is nothing in our present knowledge of those laws to deny such a possibility. In the light of this state of affairs, it is incumbent upon us to look around in the universe and learn what we can as to the way in which things seem to be going on as an actual fact. We find that the sun and stars are very hot. We have evidence that they have been hot for so long that had there been no sources available for the supply of heat, they must have cooled ages ago. All the more obvious sources of supply of heat which had been examined by the physicists, gravitational potential energy, radioactive energy, and so forth, had proved hopelessly inadequate; and it became necessary to draw upon atomic energy; and to go even further and draw even upon the energy associated with the very existence of such things as protons and electrons.

Modern physics has come to recognize a very close relationship between mass and energy, in the sense that if mass, in the sense that a particle has mass, is caused to disappear, then energy appears in proportional amount in the radiant form. If a number of protons and electrons are brought together, it is known that they lose mass; and it is believed that the disappearance of mass would be associated with the radiation of a proportional amount of energy. This relation between mass and energy, first sensed from the principle of relativity, has been verified in certain instances experimentally. The amount of energy which is the equivalent of the mass of even a drop of water is surprisingly large, so large, in fact, that the complete annihilation of the drop would result in enough energy to supply two hundred horsepower for a year. The conditions of very high temperature and pressure in the interior of the stars are believed to be favorable to this transformation of mass into radiant energy, and it is believed that in this source, by the devouring of its own substance, does the star refill its coffers of energy to pay forth continually to space that tax demanded by nature. While we do not have a complete picture of the passage of mass into energy in the sense that the materialistically minded would demand a picture, we are driven to believe that it occurs. No other source of energy seems adequate to explain the heat known to be continually radiated from the stars. Here then we see going on, as it were, the process of continual degradation of energy and of matter itself to the form

of ultimate chaos in the form of radiant heat energy. The logical end of this story would be the complete conversion of all matter into heat energy. It is true that the evidence of our experience teaches us that the devouring process would go on much more slowly when the stars were old; but eternity is long, and there is plenty of time. Is there any way back from radiant energy to matter? As a matter of fact, there is, and the method has been admitted by all physicists who are less than thirty-five years old, and by most of those who are older, as a perfectly respectable member of the society of physical methods, although the manner of its occurrence is at present exceptional. I must remind you that radiant energy exists in the form of definite units characterized in magnitude by the frequency of the radiation concerned. These units are called photons. Now the idea is that on certain rare occasions, a photon comes into such violent collision with the nucleus of an atom as to result in a kind of catastrophe. In this catastrophe nothing in particular happens to the atomic nucleus, but the photon becomes mathematically irritated in such a manner as to cause it to decide to change its existence, commit suicide and become resurrected as a pair of charged particles. If you should ask for a crude analogy, I suggest that you think of a spiritualistic seance. The photon is the ghost, the pair of charged particles constitutes the materialized ghost, and the atom is the medium. Now our ideas associated with the subject tell us that if our atom is at rest, this kind of phenomenon could not occur unless the photon had an energy enormously greater than that possessed by the kind of photons associated for the most part with heat. However, if the atom moves toward the photon with great energy so that it moves with a velocity comparable with that of light, and if we stand on the atom, the photon will appear like a photon of shorter wave length. This follows, in part, from the same principle as that which causes the pitch of a whistle to sound higher if you rush towards it, or more exactly from the theory of relativity. Thus to the moving atom, the low-energy photon will look like a high-energy photon; and the theory of relativity tells us that this fact will irritate the photon just as much as if it had been a high-energy photon and the atom had been at rest. The photon will change to a pair of particles and rob the atom of some of its energy to accommodate it in its new state of life. Were it not for the fact that we have to borrow the assistance of the high-energy atom, which high energy atoms are hard to secure in any large number in nature, this process would constitute a very suggestive one for the reconversion of radiant heat energy into matter. As matters stand, we have no suggestion from the laws of atomic physics as to the processes by which photons could become irritated without the presence of the atom. They do not possess the power to become irritated simply by their boresome existence; and, even if they did, a low-energy photon, without the assistance of an energy-lender in the shape of a fast moving atom, would not of itself have enough energy to enable it to change into a pair of particles. If we could see ways in which many photons could cooperate to produce particles, the path back to matter would be easier.

It is perhaps not without interest to contemplate a final state of the universe in which there were practically nothing but photons wandering throughout space, and compare it with what is taken by some as the starting point of our universe, a condition in which all the atoms of matter are distributed throughout a space of finite extent in the sense of the theory of relativity. It has been suggested that under such conditions the moving atoms will come together in clus-

ters under the influence of their motion and of their gravitational attraction, to form nebulae, which again under similar influences form clusters which condense to form the stars. From this simple beginning, there grows, through the action of gravitation, in feeding its energy into the motion of the atoms, a state in which the stars form and increase in temperature, producing in turn all those extraordinary phenomena such as transmutation of matter into energy, radiation of heat, and so forth, which we have only barely touched upon in this address. The question is whether, starting with a universe of photons, a similar, or rather an analogous, state of affairs can result. It would presumably be necessary to provide for laws and forces by which the photons could gravitate together, and produce conditions favorable to their conversion into matter; but, just as the effects of gravitation while present on a large scale are almost immeasurably small in the case of bodies of small size, so these forces, potent perhaps to form the basis of the recreation of the atoms, may be such as to prevent there arising conditions in which, in our ordinary experiments, a violation of the second law of thermodynamics would be found. In invoking such processes as those I have hinted at, perhaps a good test one might set himself as a test of the reasonableness of the idea is to inquire whether the process, violating as it does the spirit of the second law of thermodynamics, would, if it existed, have prevented people from going through exactly the mental processes they have gone through leading to the very discovery of that law, and to their subsequent belief in its generalized validity.

In conclusion, I would add that I hold no brief for trying to save the universe from its ultimate fate. My object has been simply to discuss the question as to whether or not that fate is inevitable in the light of our existing knowledge. The avoidance of that fate may involve some additions to our stock in trade of physical concepts. Among other things it may involve the cooperation of several photons in single acts, in the sense I have hinted, so that, to paraphrase the statement concerning the value of the work of him who can make two blades of grass grow where but one grew before, we may say that perhaps he who finds a way to make many photons act where but one would act before may have found a way to rebuild the universe.

IN QUEST OF GORILLAS

VIII. DRUMS IN THE FOREST

By Dr. WILLIAM KING GREGORY

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At Stanleyville we called upon His Excellency the Governor-General of the Belgian Congo and had the pleasure of learning that he was much interested in the gorillas and chimpanzees of the Belgian Congo and in our plans for preserving specimens for anatomical study. As we were then about to start on a trip north from Stanleyville into the great forest in search of chimpanzees, the governor very kindly advised us to go to a certain place southeast of Buta and north of the Aruwimi River, where chimpanzees were abundant. He gave us a letter to M. Libois, who had been in charge of that district and knew all the details. Accordingly as soon as we could make the necessary arrangements we left Stanleyville in a camion, bound north for Banalia and Kole.

That morning's ride through the great forest was very memorable as we passed beneath the extremely high and beautiful trees of the Prince Leopold forest reserve; many of these had shining gray trunks and immense spreading buttresses. I sat in the back of the camion on the baggage, facing the charming vistas of receding avenues of majestic trees.

We also whirled by one village after another, usually extending along the banks on either side of the road. The village folks, especially the small children, did not fail to supply a continuous entertainment. As the grand whir and clatter of the big camion approached, loaded as it was with baggage and black boys, with four real "Bullamatari" on the seat and on top of the baggage, the little boys would run forward, hesitate and sometimes begin begging for "matabish" by gestures. Then if one waved to them from the rear of the car they would respond with glee, running after the camion and waving as long as one kept it up and as far as one could see them. One could even perform experiments in producing definite reactions at a distance. For instance, if one waved his right hand, they would usually wave their right hands; if one waved both arms they would usually do the same. If one started a dancing movement with his hands and arms, they would imitate it and then start dancing with their whole bodies. Even the men and graybeards, scandalized perhaps by such unexpected levity in a Bullamatari, would often break into grins and occasionally join in the uproar.

Miles and miles of villages shot past in this way and one wondered what effects the opening of thousands of miles of automobile roads was having on the culture and view-points of the inhabitants. If the natives had been more sedentary the effects would be still greater, but as they already had the habit of carrying their products many miles to the nearest market, it is possible that the presence of the camions affected them chiefly by bringing foreign merchandise to these markets and especially by greatly facilitating the collection and shipment of large quantities of native products to the nearest ports of export, down the river and thence to the outer world. Of course the existence of the roads makes it easier for the government to control the villages and in order to

—*Photograph by H. C. Raven.*

A 32-MAN-POWER FERRY-BOAT

PARTS OF FIVE SETS OF PADDLERS ARE VISIBLE.

facilitate this still further, a great many villages have been moved to the nearest road.

That morning the camion had to cross two rivers by ferry, and here was a novel and impressive display of the way the cultures and aptitudes of the whites and the blacks are cooperating harmoniously to spread peace and prosperity over the land. For the ferry-boat consisted of a row of six immense piroques, or native canoes made of hollowed-out tree trunks, tied together into a well-spaced series of pontoons by European bridge construction and supporting a platform for two camions. The canoes are parallel to the course of the river, while the platform runs across them. After leaving the bank the gang of canoe-men, emitting the usual pandemonium, pull upstream on a line of rattan cable which is attached to floats; the end of the cable is fastened a long way above the starting-point. When the ferry-boat has been pulled far enough upstream, the cable is dropped and the gang begin to paddle madly, amid a babel of chanting and orders. Swiftly the resultant of the current and the paddling shoots the burden across and obliquely downstream to a place just above the landing; then by clever paddling the front end swings around into place. The people here were especially joyous and tuneful, but we reserve further description of this choice spot till our return trip.

To the north of these two rivers the prosaic, low-roofed houses to which we had so long been accustomed began to be replaced by a type of roof which was produced upward into a sort of gigantic pyramidal fool's cap with a queer little topknot at the tip.

At lunch-time we arrived at Banalia on

the Aruwimi River, about ninety miles north of Stanleyville; here we were met by M. S. de Medina, the proprietor of the local hotel. We learned that the district toward which we were headed had been recently flooded, that several bridges were down and that it would be impracticable to reach our objective in the short time available. We had also been told that chimpanzees were numerous in the forest around Banalia; this was confirmed by M. de Medina, who himself had killed many and who had several good black trackers to place at our disposal. After a brief conference we decided to stop at Banalia, for a few days at least, and try our luck.

Then began one of the most interesting of all our experiences in Africa, for at Banalia we were in the midst of the great forest, on the banks of a typical tributary of the Congo, where elephants and chimpanzees abound, and among a people with a rich and picturesque culture.

When we entered the large, cool, thatched dining hall of M. de Medina's "hotel" we received an agreeable shock from the spotless table linen, the faultless service and the excellent food, the best we had had in Africa. The black genius that presides over the kitchen has been with M. de Medina for twelve years and deserves to be decorated with the order of St. Boniface or whoever is the patron saint of innkeepers. Of course M. de Medina, aided by his genial hotel manager, has created this remarkable state of affairs in Africa. The cottages for the guests are of brick with thatched roofs, cool and clean.

Even within the bounds of M. de Medina's estate we were in the midst of a native village, where something amusing or interesting was happening almost every minute. But our first thought was of the beautiful forest on the other side of the broad river, so early the next morning McGregor and I got into a big piroque and were paddled, amid weird chants, a long way up against the current and almost under the overhanging branches; then we shot across and down to the vil-

—Photograph by J. H. McGregor.

A RESIDENCE STREET IN BANALIA

THE BELFRY PROBABLY ACTS LIKE A CHIMNEY, MAKING THE HOUSE COOLER AND CARRYING OFF THE SMOKE. IT ALSO ADDS GREATLY TO THE APPEARANCE OF THE HOUSE.

lage on the opposite side. A valiant little water-snake pursued our big canoe and made many attempts to board us but was beaten off by the paddles of our black boys.

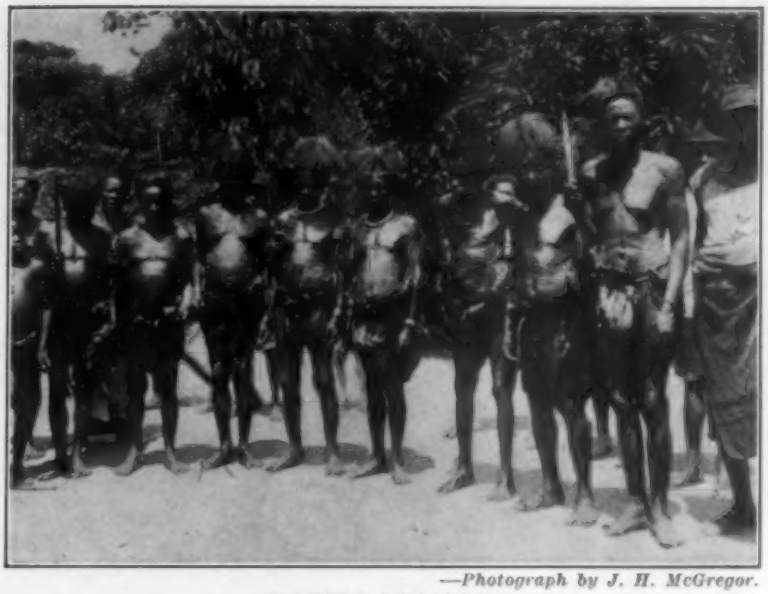
On this and other occasions some or all of us wandered in the dark and humid forest, listening intently for monkeys and chimpanzees; we saw fresh elephant tracks but very few monkeys, and we never got into close touch with the elusive sokomotos (chimpanzees). Even Raven, with all his long record of successful game stalking in many lands, tramped for days and often heard chimpanzees but was never able to deliver the definitive shot in the head that was necessary under our own requirements. The relatively few chimpanzees in this region are scattered over enormous forest areas, and whether one meets any of them is largely a matter of chance and of time. Accordingly only one chimpanzee was secured here in the week that we could spare from our journey to West Africa.

This dark forest was in most places not too difficult to get through and one seldom needed a machete, although many tangling vines and quite a few thorns would do what they could to check one's progress. One day when there were all four of us and several blacks in the forest our trail was extremely tangled and I had not the remotest idea how to get back. Even the blacks were puzzled, one pointing in one direction and one in another, but Raven pointed a third way and soon we came out on the path near the place where we had entered.

The interior of the forest is a very peaceful, shady place, silent save for the chattering of small birds or the uproar of hornbills. Insects, except for the fungus-like nests of termites on the tree trunks, are not much in evidence and the same is true of other creatures, so that one may wander all day and see very little of animal life except for birds and a very few monkeys. Many of the trees are of enormous height. The long clean trunks have a smooth light bark and immense diverging buttresses at the base. Huge "stag-horn" ferns sprout from the trunks of the trees and serpent-like lianas coil

—Photograph by J. H. McGregor.

A QUIET DAY ON THE ARUWIMI



—*Photograph by J. H. McGregor.*

IN FULL REGALIA

THE CORRECT DRESS INCLUDES A SHAKO, A HIPPOPOTAMUS GIRDLE AND A LARGE DAGGER-SHAPED KNIFE OF LOCAL MAKE.

about the branches and hang down like ropes.

The chimpanzees often come down from the trees when danger threatens and run away very quickly on the ground. Like the gorillas, they feed mostly on succulent green vegetation, but they are far more lively and emotional than these animals. They are very wary, perhaps partly because they are constantly hunted by both natives and whites.

The villagers around Banalia were glad to report to the white men the presence of chimpanzees in their neighborhood, as the latter do considerable damage to their plantations. Hence we made many excursions in M. de Medina's auto to villages in the forest through which the road ran. Sometimes Raven and Engle would leave us to hunt in the forest, while McGregor and I would get pictures of the people and the villages. On the way we saw many things of interest. Here, for instance, is a black streak across the road, an army of ants on the march, carrying their pupae in thousands, with big-jawed soldiers seeking an enemy to attack. A little further on, a cluster of butterflies, some of great beauty with iridescent blue wings. Here are the tracks of two big elephants that crossed the road only a few minutes before the auto came up and were seen by several natives, who told us about them. That unseemly uproar in the trees comes from a couple of hornbills, who utter harsh cries and fly with heavy whirring strokes, then glide for a while. There goes a "spot-face" monkey, making an enormous leap from tree to tree and getting out of harm's way as fast as he can. There above our heads is a huge wasp-nest hanging down from a tree, and M. de Medina tells us a gruesome story of a native who was stung to death by the angry wasps.

And what people one meets along the road! Here is a grizzled old chief, plodding along on his way to a conference at a village a few miles up the road. He wears a huge belt of hippopotamus hide, which is prolonged in front of him into a

—*Photograph by J. H. McGregor.*

FRIENDLY WOOD-CUTTERS

great curving prow. In this belt is stuck a long and beautiful steel blade with incised curved lines on the sides. On his head he wears an imposing shako of monkey fur, which adds to the grimness of his half-blind, wrinkled face. He is willing to be photographed in all his glory and does not need to be coaxed to accept a present of one franc.

Soon we come to a village, consisting of a long wide street with a row of "fool's cap" houses on one side and people resting in easy chairs in the sun. Ladies obligingly fluff each other's hair, infants with swollen abdomens toddle about and bright little rascals of small boys roam in search of fun. Here the high court of chiefs is assembling and we quickly line up a dozen of these dignitaries; most of them have extravagant hippopotamus girdles and monkey-fur shakos like those of the ancient we have just left behind. They look very solemn and are probably getting ready to pass some fearful judgments upon the persons they are about to try. Of course all the village male gossips want to get into this picture, but they only laugh when we push them out of the way and give the francs to their "kings." We provide entertainment for the *hoi polloi* by throwing a few half-francs ahead of us for the little boys to race for, but there is always some big bone-head who can't resist the temptation to dive into the midst and try to get there first or to snatch it away from the milling crowd of boys. Such bone-heads never disobey when we roar at them and order them out of the way. (We are rather glad, in fact, that they don't disobey, as some of them are big enough to grab McGregor and me by our necks and knock our heads together; but in such cases we invariably assume the right to instant obedience, and the bluff always works.)

Some of the painted decorations on the plaster walls of the houses stand for horses, men, fowl, etc., and probably betoken membership in some fraternal order. These designs are exceedingly crude and ugly, in wide contrast with the serious and beautiful decorations

—*Photograph by J. H. McGregor.*

THE VENUS OF BANALIA

of sword blades, spears, scabbards and household articles.

Then we go along to a village of wood-cutters, who have devastated many acres of beautiful forest, leaving half-burned stumps and dire confusion. As soon as the auto stops we are almost smothered in a crowd of grinning savages, who poke their big faces in the car and climb on the running boards. McGregor wants to get cinemas of them, and my congenial duty is to get the ice broken and the folks loosened up. We sit there a second or two and I suddenly point to a very attractive infant and in pantomime ask the mother for it. Fortunately she refuses, as I should hardly have known what to do with the squirming little creature, which is roaring its disapproval amid the smiles of the public. Then, for lack of anything better to do I point to a wooden bell, take it from a boy and signify my understanding of its use by putting it to my neck and shaking it, as their own dogs do when they have found the quarry shot by the hunters. Roars of laughter. Playing the clown has always been easy for me under congenial circumstances, so I get out of the car and by writhing gestures of shoulders and head suggest a village dance.

Instantly the cue is understood, people rush for huge "elephant's ear" leaves and tie them around their waists to serve as ballet skirts. Soon there is a madly swirling circle stamping and clapping and chanting and writhing, while McGregor reaps a harvest on the cinema. One poor old man looks on but does not join in the dance. Evidently for him life has lost its savor. I motion to him to join the ring, he gestures in a deprecating way, but I insist and soon he is stamping and whirling with the best of them.

Then all the dancers get "matambish" (a present) and we begin to take individual portraits. Here is one of the most brutal-looking blacks I saw in all

Africa—a short, big-muscled, flat-faced man with a red fez and with a lash in his hand. In the old days his lash would be a bloody weapon of tyranny, but nobody in the present crowd looks abused or afraid. Here are poor old females with leathern faces but with wheedling dulcet voices. Right next to them is a veritable black rosebud—a young girl to whom even the most crabbed misogynist must in fairness award a high quotient of feminine charm. She wears only a girdle and a narrow apron, and McGregor's discriminating cinema gets many an eyeful of this sable Venus de Banalia, recording her flowing contours, her dainty, well-poised head, her graceful arms, et cetera, as well as the delicate patterns in black tattoo pigment on her bosom and back. She has an indefinable manner of quiet confidence and good-breeding, and it is a pity that we could not make a record of her low and pleasant voice. But other candidates for the attention of the photographer crowd forward and when we try to pay her a franc, her young husband, the "captain" of the village, steps forward to claim it. He, poor youth, is entirely swathed in a grimy and forlorn suit of soiled ducks, but we are thankful that she is still a simple village maid, either too poor or with too great an investment of tattooing on her body to be eclipsed in a missionaries' Mother Hubbard. He can speak French quite well, and when later they call upon us at the hotel we send back cigarettes to the village folk and give a mirror to the little wife; she moves quietly past the tables of white folks in the dining hall, demurely balancing the small package on her head, in the dignity of her wholly modest black nudity.

That noonday we picked up Engle, who had had a long morning in the forest after chimpanzees, and later in the day we went back after Raven. After a week of constant hunting only one chimpanzee had been shot by M. de Medina's black tracker; unfortunately the animal is only a young male and the bullet has penetrated the body; we can only hope that the preservative fluid injected will reach enough of the capillaries to prevent serious decomposition.

Meanwhile around our little bungalow at the hotel amusing sights still abound. M. de Medina has two full-grown tame ostriches behind a wire enclosure opposite our front porch; once a day these awkward giants are allowed to come out and roam around the village. The fun begins when a boy with a stick tries to chase them back into their enclosure late in the afternoon. Of course they run everywhere but in the indicated direction, amid a satisfying uproar of scattering black females. One kick would knock the boy into "kingdom come," but he pursues them hotly. Finally when each ostrich gets near the gate he moderates his pace, lifting his knees high, and with upreared head and flapping wings stalks grandly into the enclosure. Another time M. de Medina's stallion takes it into his skittish head to begin bucking, pirouetting and side-stepping, and again the blacks scatter with endless jabber-quacking.

Meanwhile the dead chimpanzee, together with the four white men, proves a great attraction to the villagers, who crowd around to jeer at the chimpanzee's grotesque features and to watch the enigmatical proceedings of the white men who are embalming it. If they wonder about it all, they probably think we are medicine men of some peculiar cult.

On one occasion a man stepped forward from the crowd on our front lawn and introduced a puffy small boy, like a miniature drum major. The boy had a fearfully stodgy severe look, a great shako of monkey fur and a dwarfish rotund body. The people began to clap their hands in a slow measure and the boy started to puff his fat cheeks, roll his eyes and make his body jerk rhythmi-

—*Photograph by J. H. McGregor.*

PYTHON AND GOAT, BOTH DEAD

cally, while the people droned rather than chanted the following:

Choomba, katoomba,
Choomba, katoomba,
Choomba, katoomba, katoomba.

As the fat boy warmed up to his work, his movements and contortions became more and more violent and absurd, but he never relaxed his stern facial mask, or moved from the spot where he was standing; during the grand finale his agility was, to say the least, astonishing. About this time we began to suspect that the *motif* of this dance was not altogether decorous. Afterward the boy solemnly passed his hat around and gave the francs to his father, or manager.

That evening we watched for a short time a village dance, which was somewhat like an old-fashioned "Virginia reel," with "balance to partners" and "all hands around."

Another day a large group of women dancers came into the cleared space in front of the dining hall and went through an elaborate choral dance that lasted for several hours. The women were of all ages, from tiny children up to reverend beldames. They were fully dressed in their best cotton turbans and what looked like gaudy kitchen tablecloths. About half a dozen made up the orchestra, beating with their hands upon many kinds and sizes of drums, while the rest circled about them, swaying slowly in the dance. Their movements were rather deliberate and mostly graceful and their music was sonorous and rather solemn. There was no wild whirling or corybantic revelling, and the manager of a New York black revue would doubtless have judged the performance impossibly tame. Apparently the missionaries in this locality have succeeded in hobbling the dance but not in suppressing the African's deep impulse for it.

The leader was a very tall, comely and strong young woman with big jaws and friendly face, who gave out the song and swung her long arms and legs like a swaying elephant.

I could not get the exact words of the chorus, but I wrote down quickly the sounds, as nearly as I could record them. For instance, one movement sounded to me like this:

BA LA, monomo NAY
BA LA, monomo NAY
Ye JAY JAY; ye JAY JAY; ye JAY JAY.

A similar theme was the following:

Am ba a JAY
Am ba a JAY
Am ba a JAY

Am gan a WAY
Am gan a WAY
A WAY, A WAY (drums)

One very fine swaying chorus with wonderful minor chords sounded to me like this:

Sañta mazoúri aláya
Aláya, aláya, aláya.
Ah! oúlalala, OUla, oulaLAYa
Aláya, aláya, aláya.
On sánga mazoúri aláya
Aláya, aláya, aláya.
Ah! moula JAYa, moula JAYa
Aláya, aláya, aláya.

The throb of the drums in several movements was like this:

BUMP, billy um
BUMP, bum bum
BUMP, biddly um
BUMP, bum bum

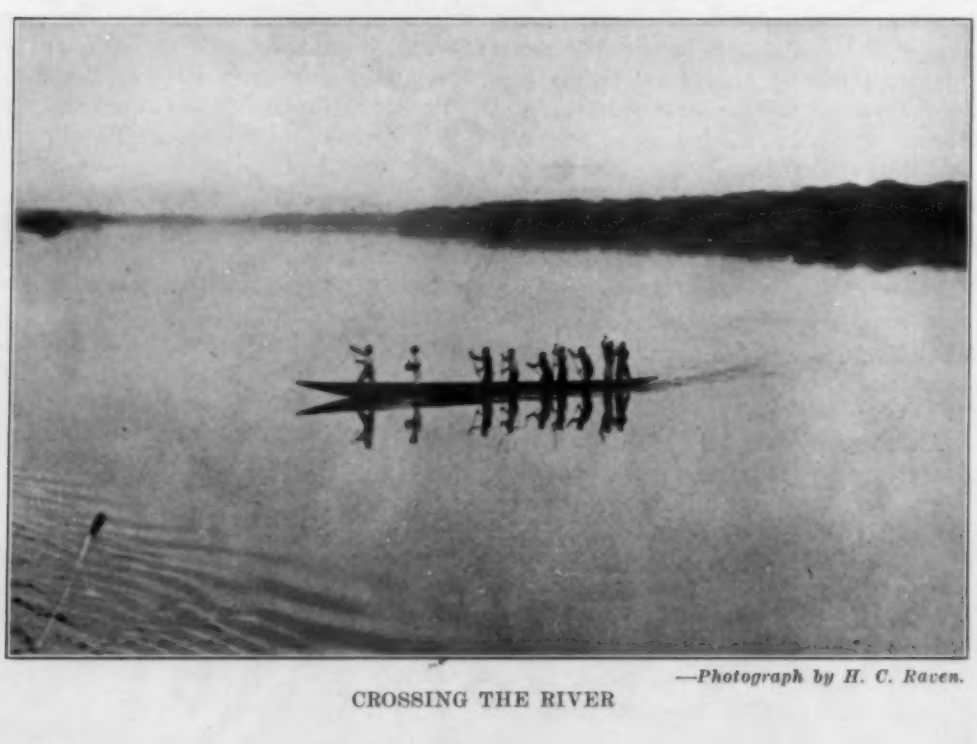
But of course it is impossible to convey in this way any suggestion of the orchestration in detail as the several drummers varied the theme. Light refreshments and cigarettes were distributed at intervals during the performance and at the end the dancers received a franc apiece.

That evening the villagers came out into the plaza to dance.

The little tom-toms and the bigger ones
Kept thumping rub-a-dub and then da-rum-dum.
First a rub-a-dub and then a dub-a-dub,
While the black folks lightly footed it.

The full moon flooded the earth with its silver light and threw the flat-topped acacia trees into delicate silhouettes, while the thatched huts cast black shadows on the pale ground. But we reclined in deep sleep in our dark bungalow.

At breakfast next morning a native came in to tell M. de Medina that on an island in the middle of the river a big python had swallowed a goat and that the owner thereof begged the white men to come over, slay the python and recover the goat. We got into a big canoe



—Photograph by H. C. Raven.

CROSSING THE RIVER

—*Sketch from author's notebook.*

WE APPROACH AN ISLAND

and were paddled swiftly up river and across to the island. There deep in the long wet grass a python lay sluggish, trying to digest the goat. M. de Medina and Engle shot it in the head and McGregor spun the cinema as the sixteen-foot serpent was drawn out of his hiding. Then began a triumphant chant as the reptile was dragged to the canoe, paddled across the river and carried to our village. But the operation of skinning the snake was interrupted by the owner of the goat, who was very indignant because the half-digested animal had been thrown into the river.

The village a little way up the road from the hotel continues to afford interesting scenes. When we go anywhere in a canoe we usually go to this village to get both canoe and paddlers. One day we saw a man cutting curved grooves in his steel blade; this he did by holding a flat piece of wood with a slightly curved edge against the blade, making the grooves with a hard steel point by following the edge of the wood.

The people have many well-made household utensils of wood, such as bedsteads, folding chairs (copied from those of the early explorers), cylindrical stools, long carved paddles. Their houses also have openings on the river-side and they have many canoes.

One day the boys were playing ball on the smooth plaza by kicking the ball to and fro. A handsome little boy with very large eyes, about four years old, was quick to recognize my approving glances and elected me as his special friend; he ran out, took my hand and walked to the hotel with me, lisping "frangha, tambac" (francs, tobacco) as his little legs went fast beside me. A half-franc now and then served to cement the friendship. One morning his father, a fine-looking savage, called at our cottage with the little chap and his two other lads. He addressed a harangue to me which Raven afterward summarized thus: You like my youngest son; these two boys are mine also. I bring you present, very big chicken." Unfortunately I did not understand this graceful gesture (which of course implied a return present from me) and rather botched the situation by thinking he was trying to sell a chicken on the strength of my friendship for his child; so I

politely disclaimed knowledge of what he was saying and referred him to our cook. However, the patient blacks are used to the rudeness of white men and no hard feeling resulted.

I went out with this man twice in his big canoe, together with his boys and about ten other boys and men. In the middle of the afternoon, when the sun had lost some of its force, Engle and I started up river in this canoe with cameras and gun. The paddlers dig their paddles quickly into the water and then, suddenly stiffening their bodies, jerk the paddles backward, relaxing suddenly as they withdraw them from the water. Their chanting emphasizes these jerky movements. When in shallow water the boat is punted with a long pole.

We go close under the overhanging branches, ducking our heads under them, and watch the muddy current swirling by. Here and there small streams flow into the river and we see tempting vistas where we could paddle into the dark forest along the winding lane. We are looking for monkeys or chimpanzees (which sometimes come down to the river), but of course we do not expect to see them until after the chorus stops. We pass several islands with an impenetrable tangle of bushes and trees; then we punt past a quiet village on a high bank, and cut obliquely across a broad expanse of the river.

As we near the opposite shore the chanting ceases and we drift in perfect silence down the swift stream. We can hear the least sound in the jungle and can see a monkey make a huge and successful leap.

As evening comes on the immeasurably wide sky is piled high with colossal cumuli, like gods reclining at an Olympian feast. Rosy light is shed from their ambrosial locks and recumbent forms, while they rest upon the darkening nimbus.

We look down the long avenue of the river and as the greens fade we begin to discern a strange mirage against the gray mist. It is the inverted image of a long canoe with moving paddles. Monstrous and sinister, the many-legged apparition crawls slowly over the river.

When we pass into the shade of the islands, the shadows of trees and bushes reach out to us with long jagged black projections that shake and tremble between moving bays of burnished brass.

When we emerge from behind the islands, the distant palms stand out as sharp silhouettes against the sky, while we move over coiling surfaces of purple and silver.

Then the huge red sun descends and its fires are reflected from the under sides of the swelling, heaped-up clouds.

On another afternoon Raven, McGregor and I went up the river with the same crew, again looking for monkeys and chimpanzees. Soon after we started the blacks shouted that there was a green snake on one of the bushes near by. The canoe was swaying, but Raven stood up, resting his rifle first on his hip and then holding it like a pistol, and shot the snake three times, the third shot nearly severing the neck. The blacks drew it into the boat and it proved to be one of the beautiful but terrible green mambas, about seven feet long; we cut off the head to preserve it and put it into a can, being careful not to touch the needle-like fangs.

Meanwhile the mist was gathering and soon it began to rain hard. We pushed the canoe under the overhanging branches and crowded into the hollow trunk of an enormous tree. As the rain increased the blacks began to crowd in there also; finally our round-faced boy Musafiri almost fell down on us from his precarious hold above. There was a fine display of gleaming eyes and beautiful teeth in this dark tree trunk, but after a while the atmosphere got pretty thick and as soon as the rain stopped we were

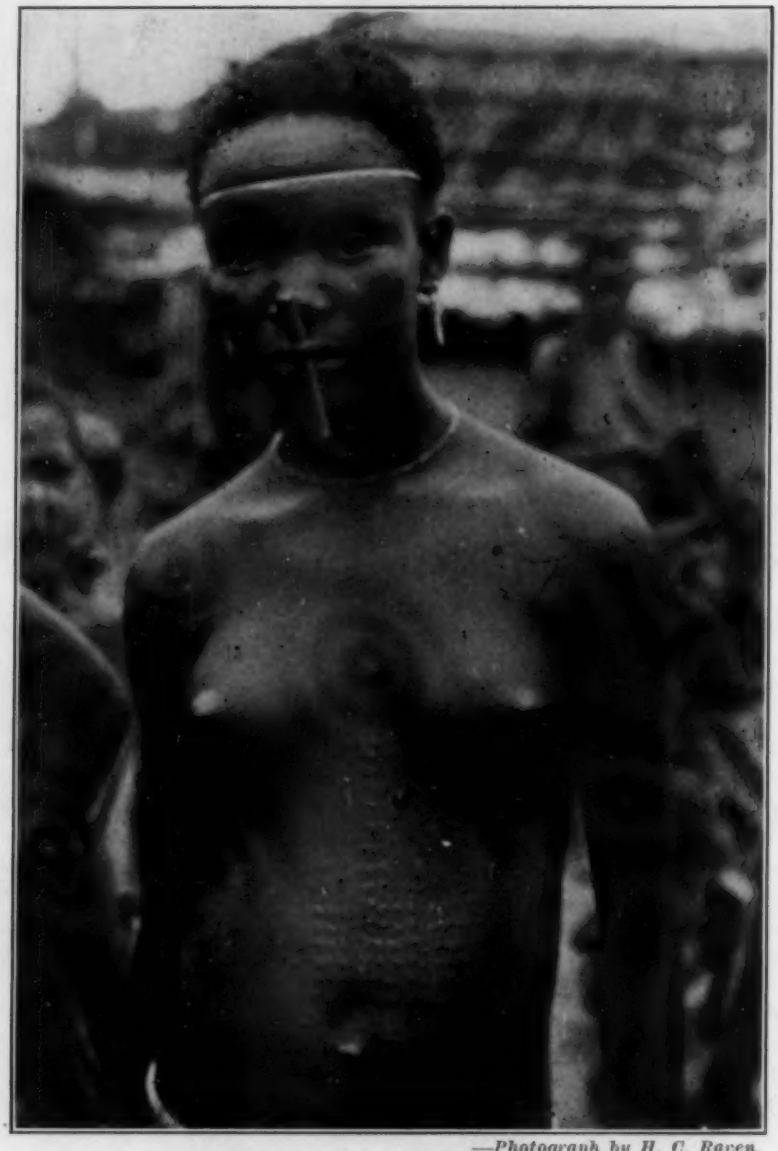
—*Photograph by J. H. McGregor.*

KEEPING UP WITH THE JONESES

glad to vacate in favor of the small ants, who seemed to resent our presence there. After the storm we went on up the river, crossed it obliquely and drifted down again, witnessing another superb sunset. This time the immense dark rain clouds were massed on one side of the river and the glowing golden and crimson clouds on the other.

We had now been in Banalia about a week without getting any substantial results except in motion pictures, and it was deemed advisable for McGregor and myself to take the camion back to Stanleyville, to be followed later by Raven and Engle. So we said good-bye regretfully to Banalia and embarked on the camion for a most interesting ride back to Stanleyville, on which we had the opportunity of confirming and extending our impressions of the trip out. Once we stopped at a village in the forest to enable our black chauffeur's assistant to purchase some smoked elephant meat, presumably from the pygmies. The elephant had been denied a decent burial for a long time before the meat had been smoked and the meat itself was still pleading eloquently to be buried.

It was not until late in the afternoon when we approached the first ferry that the fun really started. The ladies here had a queer way of sticking long stems of grass or short grass stalks vertically through a hole in their lips or horizontally through a hole in their noses; one old dame managed both decorations at once. They were somewhat coy at first, but as I felt that a little clowning might start things going, I stuck my head out of the back of the camion, waved my helmet and held a walking stick horizontally between my nose and extended upper lip as if it were a huge nose stick, then vertically as if it came through my lip. This started the laughter and McGregor reaped a cinemaful of the latest things in nose and lip sticks and chic tattooing of bosoms and stomachs. After paying those who had been photographed we tossed a few francs for the boys to scramble after. While this was going on a couple of poor old souls with babies to carry, who did not feel equal to plung-



—*Photograph by H. C. Raven.*

THE LATEST IN LIP-STICKS

ing into the crowd for francs, glided up to me with the most plaintive, pleading and persuasive soft voices and whispered "Matambish, matambish." I managed to slip them each a franc and climbed quickly on to the camion to avoid being mobbed by the others.

We crossed the river in the manner described on page 518. But as we slid into the ferry-landing on the other side, the villagers there, no longer able to restrain their impatience, broke into a wild uproar and dance. Savage-looking men, slender maidens, youths and little children hopped up and down, dumpy women flopped up and down, and all loudly chanted their joy at the approach of the strangers, who were, no doubt,

about to fling largesse as the sower scatters the seed. As the camion chugged up the slope the population dashed at it from all sides and nearly stopped it with their rush. But a few half-francs thrown to one side started them all off in that direction.

When we reached the second ferry it was almost dark and the people were huddled in their houses, only a few coming out to paddle the ferry-boat across. After that we went over a long avenue of oil palms and upon arriving at Stanleyville we said good-bye forever to the unembalmed elephant meat and went in to dinner at the hotel.

Meanwhile Raven and Engle had been forced to give up our attractive tentative plan of making the rest of the trip across the continent by auto. We had hoped to go by camion northwestward from Stanleyville to Buta; there is a great elephant farm there for the domestication of the African elephant, and we hoped to get some interesting cinema records of these animals. From Buta we had planned to go northwest to Bangui in French Equatorial Africa and from there westward to Carnet on the Sanga River, thence southward to any one of the many places where the West African gorillas were reported to be numerous. But at the hotel at Banalia a gentleman who had recently been over the road in a light car told Raven and Engle that long stretches of the road were very bad, with bridges down and sandy stretches where a heavy camion would encounter great difficulties in getting through. In view of the fact that three out of four of us were expected to be home not later than the middle of January, it was deemed imprudent to risk such delays and it was decided to take the less interesting but surer way of going down the Congo River on one of the big river boats. Raven was therefore forced to make a trip to Stanleyville, back to Banalia and back to Stanleyville again, in order to get equipment ready for the river trip by the next boat, which was to leave three days later.

On his way back to Banalia the camion at night stopped in a heavy rainstorm to offer assistance to a car which was ditched and bogged. The white driver had compelled the natives to come out of the village to help him get the car out. One of the natives addressed a long harangue to Mr. Raven, complaining of their grievances in being compelled to work in this way; but they feared the police and the brass collar about their necks and so worked away until both cars were able to start, when they were doubtless glad to receive the francs that were paid to them.

The passenger in the first car was a very agreeable young American, Mr. Curtis Mitchell, who was making a quick trip across Africa, partly by auto; we later traveled with him down the Congo. Both cars arrived at Banalia late that night, and Raven and Engle came back the next day with all their baggage. Then began a hurried reassembling of all the baggage, part of which had been left at Stanleyville, and a strenuous time of resorting and repacking for the long trip to West Africa. It was decided that Engle, who had to return home first, should remain in Stanleyville for the boat following ours. This would give him an opportunity to visit the hospitals in Stanleyville and other cities on the Congo and to arrange for the photographs of feet, hands and wrists of natives, desired by Dr. Morton.

(A further article in the series entitled "In Quest of Gorillas" will be printed next month.)

THE LIFE OF THE PEOPLE

By Dr. T. D. A. COCKERELL

EMERITUS PROFESSOR OF ZOOLOGY, UNIVERSITY OF COLORADO

WHEN we consider the life of the people, we are concerned not only with the causes of death, but also with those innumerable influences which impair the vitality of the living. Among the lower animals, the reproductive powers are commonly such that of necessity the vast majority of the offspring must perish before reaching maturity. Were it not so, the excessive overpopulation would soon cause disaster, both to the species immediately concerned and other species living in the same country. The various means by which this overpopulation is prevented, the preservation of the "balance of nature," the struggle for existence which paradoxically succeeds because it fails, these are topics of the greatest interest to the biologist, and not without some significance in relation to sociology. The human species reproduces slowly, but even so, overpopulation soon results if all checks are removed. In 1927, when I was in India, there was an important medical conference in Calcutta. One of the principal speakers said: "For many years we have striven to teach the people of India how to obey the laws of health and control the preventable diseases. *Suppose we should succeed!*" India was already overpopulated, in relation to the existing facilities for living, and the poverty and disease were appalling. We went to Agra to see the Taj Mahal. On the way, the train began to fill up with all sorts of people, and on asking the reason, we learned that there was to be a partial eclipse of the moon. This rendered the Hindoos ceremonially unclean, and hence they had to go to Benares, and bathe in the waters of the Ganges, which naturally became contaminated with all the filth of India. The half-dreaded success of the medical officials did not seem to be imminent.

Has it "pleased providence" that these things should be? When we compare mankind with the lower animals, we find some important differences. In the first place, the long period of infancy (using that term in its legal sense) involves a large capital expenditure, not merely in money, but in loving care and thought. Look at any large crowd of people, and bring your mind to bear on the thought that they all were once babies, and had to be raised and cared for and educated. They represent an enormous investment, which should be expected to yield returns. Then again, the length of normal human life is such that its impairment through disease and through defects in the economic system results in so much misery that it could be maintained with plausibility that man is the most unhappy of all animals. As Wallace pointed out, while animal life is destroyed wholesale, it is for the most part healthy and happy, to be terminated suddenly and with little suffering. This is not universally true—consider, for example, the caterpillar with parasites slowly devouring its body—but even when death comes slowly, with a maximum of discomfort, the animal is not as sensitive as man, and has not his gift of worrying. Regarding life as a whole, in a purely objective way, it seems that nature has reached her greatest refinements of cruelty in her highest creation.

Very many people, in various places and in various times, have accepted all this either as the effects of blind fate or the will of a divinity. An oriental belief is that our sufferings represent punishment for misdeeds in a former life. The modern philosopher can see a certain justification for these ideas, but the pragmatic "man in the street" is coming

to a very different conclusion. He finds that he is endowed with intelligence, which can function to protect him from evils, and when he sees what has been done within a few years, he is appalled to think of the losses and wretchedness of past ages, due to causes which are now seen to be preventable. If he considers what providence or the deity has to say about it, he supposes that just as he is made to eat and work and move about, so also is he made to think and to apply the results of his thinking to his affairs.

Considering what we now know, and the probable results of researches to be carried on in the not too distant future, it is not too much to say that if we could overcome the psychological difficulties, it would be possible for the earth to be populated by people, not too numerous to be adequately supported by the means available, normally living to an advanced age and having essentially happy lives, free from most of the diseases and disabilities which now distress us. Under such conditions, we should not speak of the overproduction of goods. Every scientific discovery productive of more abundant resources, every invention increasing our command over the forces of nature, would in effect bring multitudes of human lives into the world, because it would provide the means for their existence. Our reproductive capacity would always be sufficient to meet the requirements.

According to the government mortality statistics, 1932, the death rate (excluding still births) per estimated 100,000 population in the registered area of the Continental United States was 1,755 in 1900, but only about 1,059 in 1932. It has steadily decreased in the last five years, notwithstanding the depression. Dr. H. Emerson, in the Encyclopedia Britannica of 1929, states that within the previous fifty years the birth rate in the United States has dropped from approximately 40 per 1,000 to 21. From 1919 to 1929 the rate dropped 16.3 per cent. in the birth registration area, and 17.9 in New York City. But this does not mean extermination. The population has steadily increased, the present registration area in the ten years ending with 1932 showing successively in millions (lesser fractions not counted) 90, 91, 93, 94, 96, 97, 98, 100, 101, 101. Considering modern restrictions on immigration, it is evident that the saving of life has given this result.

Dr. Emerson (1929) estimated that the people of the United States still suffered from preventable disease, cutting short the reasonable expectation of life by about twelve years. Suppose this twelve years to be added, will it be a genuine advantage? Will it mean the prolongation of senility, with waning powers and little satisfaction? Formerly, it might have appeared so, but to-day we not only prolong life, but also efficiency, and the later years need not be lacking in usefulness or satisfactions.

My friend, Dr. Frank R. Spencer, has given me the following figures. Since 1900 the death rate from tuberculosis has been reduced 64 per cent., for diphtheria 89 per cent., for typhoid fever 88 per cent. During this period the span of life has been lengthened 10 to 15 years. In 1900 only one child in five lived to be more than five years of age. Now only one in five fails to live past the five-year age. Cholera, typhus fever, yellow fever, the bubonic plague and many other diseases have been abolished from the United States. Dr. Emerson (1929) noted that fifty years ago one out of every four babies born alive died in the first year, now (1929) only one in sixteen died. All this applies to the registration area of the United States. In Great Britain there were astonishing gains even during the war period. In 1914 there were 57,994 deaths from tuberculosis; in 1924 only 46,756. In 1914 infants under one year died to the number of 105,681; in 1924, 65,259. At the same time, the Post Office Savings Bank deposits increased enormously, and the hours of labor were cut down

from about 55.5 a week to 48 a week. The consumption of potable spirits, retailed, was reduced to approximately half.

How has all this been brought about? Through scientific research, through education resulting in greater intelligence and through the enactment of laws. The general standard of living has been a potent influence. During the war, Dr. L. Farrand, then president of the University of Colorado, went to France as head of the Commission on Tuberculosis. He told us that while he was there ostensibly to deal with tuberculosis as a separate problem, he had in fact to consider the whole life of the French people: their habits, their sanitation, their food, the fresh air question, and so on. It must always be so, and when we ask how tuberculosis or any other preventable disease can be conquered, the answer is that it must be attacked on all fronts, with every means at our command.

Few people know much about the researches which have saved many more lives than the generals and statesmen have destroyed. I have a list of the Nobel Prize winners in medicine, 1901 to 1934. Some of the work has to do with particular diseases, as that of von Behring on diphtheria, Ronald Ross on malaria, Laveran on malaria, Banting and Macleod on diabetes, C. Nicolle on typhus. In many cases the prize was given for fundamental work in physiology, not at first appearing to have any particular medical significance, but actually building the very foundations of medical practice. One of the great problems confronting every physician, every sociologist, every teacher, every individual in his own life, is that concerning the precise significance and nature of heredity. We may not believe, like the Japanese, that we are penalized on account of personal sins in a former existence; but we know the germ plasm is continuous, and that we are part of ancient life, and are subject to its laws. For good or for evil, we have inherited certain qualities and potentialities, and we must make the best of them, in health or in disease. Hence it happens that T. H. Morgan, now of Pasadena, receives the Nobel Prize for medicine, although his work has been in genetics, principally researches on inheritance in the fruit-fly, Drosophila. Babcock and Clausen, in their admirable work, "Genetics in Relation to Agriculture" (1918), put at the beginning of their book a colored plate of Morgan's fruit-flies. Thus the truly epoch-making work of Morgan lies at the roots of both agriculture and medicine, although on casual examination it appears to be related to neither. It is interesting to note that the prize-winners come from many countries, six from North America. The influence of the Pasteur Institute in Paris and the Rockefeller Institute in New York is very noticeable. An important point is that most of the work, at its inception, or even throughout, was directed to the discovery of significant facts concerning life, without so-called practical or economic ends in view. At the same time, it was well understood by all the workers that more and better information about the workings of cells, organs and organisms would make it possible to deal more successfully with the problems of health and disease. It was not forgotten that unexpected practical gains of great importance sometimes emerge from a severely technical research into scientific theory. The effect of legal enactments, such as those of California relating to milk and the pollution of streams, need not now be stressed, though they deserve a lengthy discussion. It must be insisted that laws result from public education, and in a democratic country, at least, are the expression of the opinion of the majority. The formation of that opinion is a task, not only of the teachers and doctors, but of every intelligent citizen. On all occasions, appeal must be had to the knowledge we possess, and the fundamental laws of nature, to which we necessarily have to conform. Nature, in

imposing her penalties, has no consideration for ignorance or misinformation.

It is a mistake to suppose that everything must be done by law. It is difficult to make an estimate, but it is evidently true that the influence of individual and community initiative has been a leading factor in the great advances described above. A very good example is that of rickets, a disease principally of children, in which the bones are soft and bend under stress. I well remember hearing a great deal about rickets in England in my earlier days. Many efforts were made to restore the little patients to normality by means of supporting braces. But it came to be understood that the disease was due to malnutrition, and later the anti-rachitic vitamin was discovered. With our present knowledge, rickets is a preventable disease, and to-day the care of children is sufficiently intelligent, as a rule, to prevent it.

Very great gains have been made in respect to diarrhea and enteritis, the curve descending in nearly the same manner as that for tuberculosis. The reduction of infantile diarrhea has been a principal means of cutting down infant mortality. Curiously, the automobile has had a good deal to do with this. With the coming of the automobile, the horse has been nearly eliminated in cities, and thus the horse manure in which flies usually breed. Flies mechanically carry on their feet the germs of intestinal diseases, and when they were abundant were the indirect cause of innumerable deaths. However, it is not all due to the flies. The modern milk bottle and the modern regulation of dairies have been very important factors. When I was in Australia in 1928, I heard people lamenting the small population, and the difficulty of getting worthy immigrants. I heard that they did not yet know the closed milk bottle and I said, "Your best immigrants are your babies; improve your methods and save their lives." Still another factor is of great importance in connection with diarrhea and with typhoid. That is the pollution of water supplies with human excrement. Dr. Edward N. Chapman (*Colorado Medicine*, 1934) has shown that the principal rivers of Colorado are grossly contaminated with sewage, and has published maps showing the counties in which the death rates from typhoid, diarrhea and enteritis are abnormally, indeed scandalously, high. They are precisely those receiving the contaminated waters.

We have very good reasons for believing that great advances can be made, and will be made, in the future. We are largely depending on the results of research, but research will be sterile if not utilized. We could do very much with the knowledge already available. Dr. Gerald B. Webb (*Colorado Medicine*, October, 1933) notes that the infant mortality rate in 1932 was 58 in the United States, only 31 in New Zealand. It is true that New Zealand does not have the same burden of poor and illiterate people as many parts of the United States, and that consequently our problem is a much more difficult one. Yet it would seem that there should not be such a discrepancy as the figures indicate. According to the statistics quoted by Webb, in 1932, the infant mortality per 1,000 in Fort Collins was 143, but in Boulder only 32. Figures like these may be partly accidental, the actual numbers being small. Also, Fort Collins doubtless suffers from the numbers of Mexicans, who are imported for work in the beet fields. Thus statistics do not always mean what they seem to, and it is proper to investigate the facts back of them.

The most convincing figures are those which, taken over a long series of years, show a continuous change in the same direction. Thus the death rate from tuberculosis in New York City, per 100,000 population, fell as follows in five-year periods, beginning with 1890, and giving only approximate figures: 350, 300, 250, 225, 210, 200, 110, 100.

The last date available in this series is 1925. Many such statistics, equally convincing, can be cited.

Dr. F. Ramaley informs me that his brother, Dr. L. Ramaley, is concerned with public health in St. Paul, Minnesota, and goes to all the schools, public and private. They give all children the new preventive treatment with toxoid, for diphtheria, and here is the astonishing result. Before this program of vaccination they usually had about 700 cases of diphtheria annually in St. Paul; in the last two years they had only about 40.

It must not be supposed that all diseases are subject to efficient control. So much has been done in the past that it is hazardous to predict that control is impossible in any case. The extraordinary influenza epidemic of 1918, affecting most countries of the world, may have been due to some mutation of the causative organism, but in any case it came on us like an avalanche, and got quite out of control. It was a major disaster, like a great war, but fortunately without the legacy of bitterness and hatred following war.

Infantile paralysis, with which we are now especially concerned, is still essentially anarchistic, dealt with more or less blindly, as malaria and yellow fever used to be when I was young. But we do know this, that many cases, taken in time, can be practicaly cured by suitable treatment. It is surely a social obligation to see that such treatment is available for every stricken child, and such funds as are raised by the President's Ball, and by such organizations as the Rotarians, can be thought of as entirely well spent. Individuals may not be able to contribute very much, but all together, they can very easily meet the need of all the infantile paralysis cases in the country. It is a good thing to ask the public to contribute to such funds, not only as a way of raising the money, but also for the purpose of enlisting interest and securing cooperation. It would be a sort of misfortune if some individual or the government could take all such burdens off our hands, and leave us ignorant of and indifferent to the sufferings of the afflicted.

Finally, it must be said that many crippled or disabled persons, whatever the cause, can not be restored to normality by surgical means. For such persons it becomes a problem to make the best of the situation, and in some cases that best is extraordinarily good. A blind man (Fawcett) was once postmaster in England. Huia Onslow, who broke his spine when diving in the Tyrol and could only remain on his couch, his lower limbs useless, nevertheless did some scientific work of first-class quality, his most important paper being published by the Royal Society. Infantile paralysis, so disastrous in many respects, does not affect the mind. President Roosevelt, whether we approve his policies or not, must be recognized as having an extremely keen mind and strong personality. In Colorado we have Signa Carlson of Greeley, for many years confined to her bed, doing the most beautiful weaving, showing not only manual skill but excellent taste for color and pattern.

In the midst of a troubled world, in which there is so much to lament, so much to fear, it is encouraging to note the good that has been done and is being done. It is not stressed by the newspapers, and for the most part it comes quietly and with little public discussion. It is worth while to stress it more than we have done, if only to give us encouragement and hope for the future, and more respect for our species. Furthermore, it is something in which we can all have a part.

LIFE-SCIENCE AND MAN

By Dr. OSCAR RIDDLE

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WE living in these many states are not a thinking people; yet there is in nearly all of us something which makes us wish that we, our neighbors and our children were just that. This wish is ours because we see our neighborhood and home and offspring thus made even more pleasant and valuable than they now are; and perhaps also because, in these days of shattered governments abroad, we could all feel nationally more secure if we were a more thoughtful people. Again, this wish which so many of us hold in common is enough to make us worthy humans; for, though we are not a thinking people this probably means merely that we have failed to train for thinking. A man becomes one of several rather different things according to the kind of training he gets. As a student of life-science and the background of man I am convinced that by nature man is more thoughtful than we now are. It should therefore be easy to increase this natural tendency, and the thought I bring here is that we can make ourselves, our community and nation better—more thoughtful and more secure—through training that our secondary schools should give.

The primitive savage is kept constantly alert by ever-present danger. He is constantly thinking about the meaning of what he sees and hears. His life and the continued existence of his tribe depend largely upon his quick and correct interpretation of sights and sounds and upon a sure and ready use of whatever his environment offers for his advantage. "Civilized man, freed from the stress of savage life, gets into the habit of not thinking. His actions become automatic. He gulps down whatever is served up to him" (Kerr). Civilization and sheltered childhood have removed many a stimulus to thought, and few things in the training of the citizen now seem more important than getting him back to the primitive habit of thinking constantly and effectively.

Early phases of human society, as represented to-day by nomadic hunting tribes, made much use of what we should now call science in the education of the young individual; that youth was taught to observe accurately the phenomena of nature, dead and living, to draw seemingly correct conclusions and to regulate his actions accordingly. In our own early history science undoubtedly played an equally important part in the training of the young. Even down into the Middle Ages, it supplied an appreciable part of the studies of the educated man. In later times, however, from the renaissance of classical learning onwards, science has been kept in the obscure background of our educational curriculum; the course of study for our high schools to-day remains largely literary and classical.

Thus this bit of history brings out the strange fact that almost coincident with the relatively recent period when some men began to get bits of really penetrating insight into nature—as others were doing with the classics—our training in science became poorer and less adequate than before. Moreover, in recent times, when our communal unit is not tribe or clan but thickly populated nations, we are most removed from tribal guidance in the study of nature, and also decidedly most in need of a common

knowledge and interpretation of the crowded world in which we must all live together. It would seem quite impossible that our modern bee-hive aggregations of men can satisfactorily or even actually persist without wide-spread familiarity with the nature and resources of ourselves and our communities. Because of the large extent to which personal adjustment must be made to other living things we shall now and hereafter need to make large use of the principles which rule in the living world. Life-science has become not only a great treasury of vitally important knowledge; it is also a method of learning how men may live together.

For some centuries the sciences have of course had a sort of home in the universities. But only within the life-span of many men now living have any of the sciences been generally considered proper objects of study outside the college. In his essay entitled "What Knowledge is of Most Worth," written some seventy years ago, Herbert Spencer set down the plainly convincing reasons for the special place of the sciences in general education. At present the minute amount of biology taught in the secondary schools of this country gives so poor, and often so wrong, an idea of what is in mind here that I use the term "life-science" instead. Since Spencer discussed at length the place of biology in education and since the subject was ably restated a decade ago by Professor Kerr (*Nature*, August 14, 1926) of Glasgow, my own presentation can be neither very original nor new; but so rapid has been the development of life-science that each decade provides a firmer basis for a restatement of the special values of this science to youth and to the training of the future citizen.

The writer Joad has well said: "One of the most disquieting facts about modern civilization is the failure of our social wisdom to keep pace with our material power. Science has equipped us with powers fit for the gods, and we bring to their use the mentality of babes and schoolboys." In considering this thought let us follow Kerr in indicating that in the new age it has become difficult or impossible for the untrained citizen to choose between true and false leadership to "social wisdom." Yet, at all times and among all peoples, the welfare and success of man have been closely related to his selection of leadership. In our day science and industry have given us such facilities for distributing the printed and spoken word that the method by which we humans formerly chose our leaders has been much disturbed. Primitive tribal communities, whether small or large, usually selected an outstanding personality—their ablest man—as their chief; and without such leaders during a half-million years one may well wonder how many caves and forests would now shelter the scanty survivors of the human race. But, along with their many blessings, modern printing and particularly the ultra-modern talking picture and radio provide the new disturbing factor—since they give enormously increased importance to elements of individual personality quite distinct from general strength and capacity, mental and physical. Conspicuous among such elements are oratorical power and skill in pleading special causes. The real leader is no longer forced to the front by the sheer power of his outstanding constructive ability; to a great extent first place is now taken over by the power of effective writing and speaking. Responsible posts of leadership of public opinion and of the modern state have thus become accessible to the skilled orator, even though his constructive ability in statesmanship may be of quite low order. America and the world now require a new defence

against their inevitable orators, mimics and emotional giraffes.

Clearly this development involves serious dangers to all peoples. It seems equally clear that one of the main tasks confronting each community is the devising and setting up of those educational safeguards which alone can be efficient against these dangers. Though all science probably provides partial safeguards, we may now consider a very few of the special and irreplaceable things which life-science can do for the citizen. To make its proper contribution life-science should be granted a continuous four-year place in the course of study of secondary schools.

Life-science can present the great fact of organic evolution. The origin by descent with modification of complex life, including man himself, and the kinship of all living things are included in this preeminent principle. In the center of all this we discover the principle of progress deep within ourselves; and the outlines of the rules and laws of that progress may and should become the common denominator of all thought about life.

Life-science presents the broad and humanly momentous principles of inheritance: How and why the offspring find repeated in themselves the characteristics of their ancestors; knowledge and understanding of differences or variation among offspring; the utilization of these principles in the improvement of races of animals and plants upon which human existence depends; and finally, the full realization that on the basis of their heredity no two men are exactly equal. Indeed, the very mechanisms by which we begin life, and the inner hereditary forces which attend our growth and development, assure us that all men are *un*equally endowed by nature. So significant are these well-established principles that we ask: For how long and to what extent dare communities, and their ever more complicated social and legal regulations, disregard this basic fact of the biologic inequalities of men? Here are questions for us all to decide; and how shall just and satisfactory decisions be obtained and enforced unless all know the facts upon which the decisions are made?

Life-science now presents the inspiring facts of the plasticity or modifiability of the growing organism. In much the same way, and using some of the same tools by which life-science has obtained control over many diseases, it has now made substantial beginnings in controlling the growth and attainments of plants, animals and of man himself. Depending upon which rays of light man selects to attend its growth the soy-bean can be made to become either a twining vine or a sturdy shrub; rats growing under all usual conditions may attain their usual size, but, by adding much more of certain vitamins to their food-supply throughout the growth period, man can now make them grow to twice their usual size; on man himself—throughout the civilized world—those little human dwarfs known as cretins are having inches added to their stature and new power added to their brains by the use of a secretion taken from the thyroid glands of an ox or sheep. Best of all, these and hundreds of kindred things are things always repeatable under the prescribed conditions—they are in no way at the caprice of magic or of wishful thinking. What a world of wealth and inspiration is this to the unspoiled youth—the future citizen—who thus learns of man's fast-growing power over even his own destiny!

Life-science—thanks to laboratory triumphs for almost each one of the last twenty years—now presents a handful of vitamins with which any youth may cure certain diseases; and better still

with these he can assure himself freedom from these diseases. This simply statable knowledge is needed by all, and all of it is particularly useful to the young. Shall we teach it in our schools? Or shall we leave it—like most other practical information about our natural environment—to the extra-curricular activities of groups such as the Boy Scouts.

Life-science presents the ever-present and pervasive fact of the struggle for existence with the consequent elimination of the unfit. The young citizen will learn that in our civilized communities the harsher aspects of that struggle are not present; that the individual no longer depends on his perfect bodily fitness, on the acuity of his senses, on the alertness of his mind, to survive and reproduce. He will know that this incidental denial of a rule of nature may or must have profound effects upon the future of man. He will find much food for fruitful thought in the dilemma that, unless we develop and use a far-reaching control over our own development, our high civilization will lead to the deterioration of the individual in his all-round fitness, both mental and physical; and that this retrogression—already in evidence—renders him correspondingly more and more dependent upon the community for his welfare. Emerging from these considerations, we find some assurance that with higher and higher communal evolution—with more and more intimate dependence of the individual upon the community—we should have greater and greater attention paid in our educational system to those subjects which have to do with the citizen's relations to and duties towards the community—duties such as discipline, ethics and loyalty to country and comrades.

Concluding this statement: The biologist would like to see a movement of our whole educational system away from the merely literary, doctrinaire, academic regions in which it is apt to be out of touch with the reality of biological fact and practical affairs. He would like to see men trained for citizenship and as comprehending members of a community. He would like to see a far more general recognition of the fact that the primary object of education is to make the individual able rather than learned. A learned individual may be, and often is, a stupid one. The brains of most of our youth are capable; let us stimulate and reward their continuous activity, and let us—in school and out of school—avoid giving them those easy assurances and sedatives which only put them to sleep.

THE COMPOSITION OF GLASS

By Dr. GEORGE W. MOREY

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GLASS plays an important part in the researches of the Geophysical Laboratory of the Carnegie Institution of Washington. In our investigations on the genesis and evolution of the rocks formed by the freezing of a molten magma we study the melting and freezing of artificial minerals and their solubility in similarly constituted molten siliceous mixtures. The success of our studies is largely due to an experimental method of great power, which was developed at the Laboratory. It is called the quenching method and is based on that property of silicates which makes possible the formation of glasses.

HEATING AND COOLING CURVES

When the Geophysical Laboratory's researches on silicates were begun, the only method available for the study of melting and freezing was that of heating and cooling curves. In that method, to determine a melting point the crystalline material is heated slowly, with continuous recording of the temperature. When melting begins, the absorption of the quantity of heat necessary to change the crystal to a liquid causes the temperature to fall behind that of the furnace and to remain approximately constant until melting is complete. That approximately constant temperature is taken as the melting point. Similarly, when the melted material is allowed to cool, at the beginning of freezing the setting free of the heat of transformation from the liquid to the crystalline condition causes the melt to cool less rapidly than the furnace and to remain at approximately constant temperature until freezing is complete; and again the constant temperature gives the freezing point.

That method works beautifully with metals and the common salts, but not with most silicates (Fig. 1). With those silicates of greatest interest it is impossible (Fig. 2). As a rule, when a molten silicate is cooled, instead of crystallizing at the freezing point the liquid persists unchanged, and in most cases can be cooled to ordinary temperature without freezing. It gradually becomes stiffer and stiffer, more and more viscous, finally reaching a condition of viscosity in which, for all practical purposes, it is rigid. In other words, it becomes a glass, and at ordinary temperature the glass will persist almost indefinitely. It is this characteristic of silicates that makes possible the glass industry.

Nevertheless, the glass has a natural freezing temperature usually within that elevated temperature range in which it is still soft enough to deform more or less easily. A little below the natural freezing temperature, the glass is inherently unstable, and by long-continued heating a little below its freezing point it can be transformed, in part or entirely, from the haphazard disorderly atomic distribution which characterizes the liquid into the orderly array which characterizes the crystal. The molten glass can be frozen to a crystalline aggregate, but the transformation is not prompt and inevitable, as is the case with a molten metal, but must be coaxed. Once developed, crystals can be redissolved only by heating above the freezing point of the mixture, and then they dissolve with comparative rapidity. The process of solution is dependable, and if the crystals do not dissolve, the sample being tested is below the

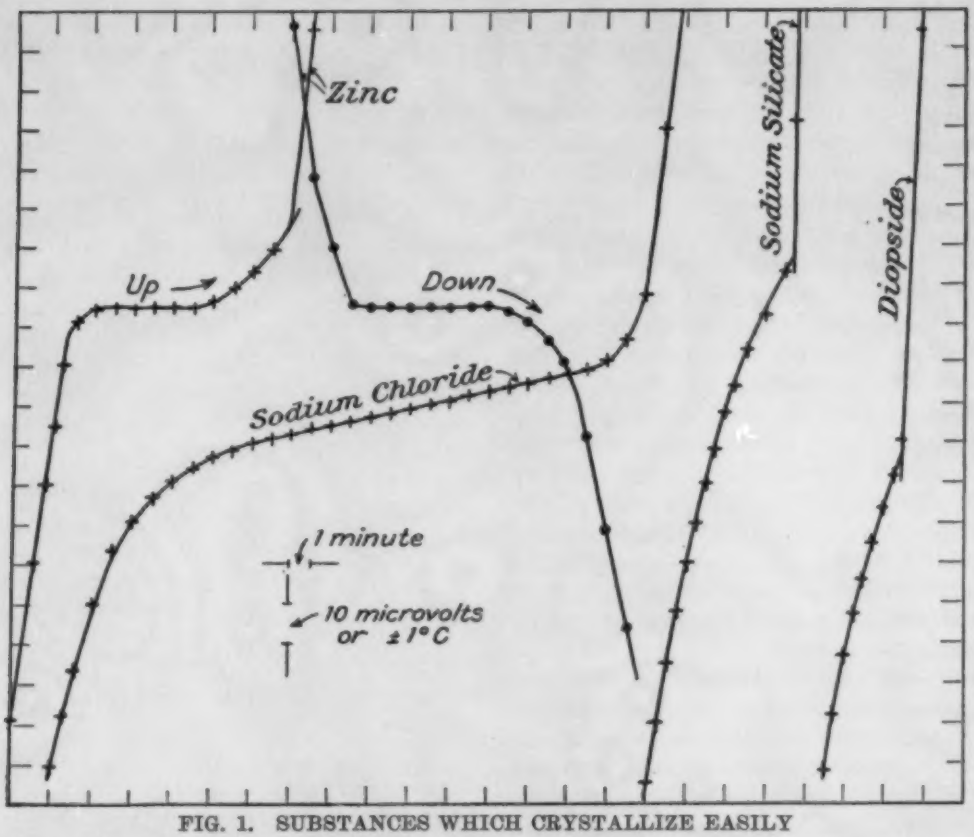


FIG. 1. SUBSTANCES WHICH CRYSTALLIZE EASILY

THE STUDY OF MELTING AND FREEZING BY MEANS OF HEATING AND COOLING CURVES. THESE CURVES ARE TYPICAL OF THESE OBTAINED WITH METALS, SALTS AND SILICATES WHICH CRYSTALLIZE EASILY.

freezing point, while if they dissolve, the temperature is above the freezing point.

THE QUENCHING METHOD

It is by taking advantage of this characteristic of most silicates that the quenching method was developed. Mixtures of the component oxides which make up the minerals to be studied are melted to form homogeneous liquids. By a heat treatment at the requisite temperature these liquids are crystallized, to one pure mineral, or a mixture of two, three or more minerals, depending on the composition. Then small quantities of this crystalline mixture are held at various constant temperatures for a time long enough for the melting reactions to go to completion. The charge is then quickly cooled, or quenched, usually by dropping it into mercury.

Because of the characteristic sluggishness of the crystallization process in silicates, the cold charge is in exactly the same condition as at the temperature of the experiment, and examination with the microscope tells what that condition was. If the quenched charge is all glass, the experiment was above the melting or solution temperature of any of the crystalline compounds corresponding to that composition. If all crystalline, the temperature was below that of melting. If a mixture of glass with one kind of crystal, it indicates that partial melting had taken place, with solution of all but one

of the kinds of crystals. By systematically proceeding in this manner, the exact melting relations in a mixture of minerals of different proportions can be determined with precision, and that is the way in which we have worked out the relationships between crystals and liquid in a large number of systematically varied mixtures containing the rock-forming oxides, Na_2O, K_2O, CaO, MgO, Al_2O_3, FeO, Fe_2O_3 and SiO_2.

History of Glassmaking

During the course of this work glasses of widely differing compositions have been prepared in the Laboratory. Most of these compositions have no resemblance to commercial glass types; and none of the new glass compositions are suitable for glass manufacture. The only compositions we have worked with that are suitable contain as their principal ingredients soda, lime and silica, and

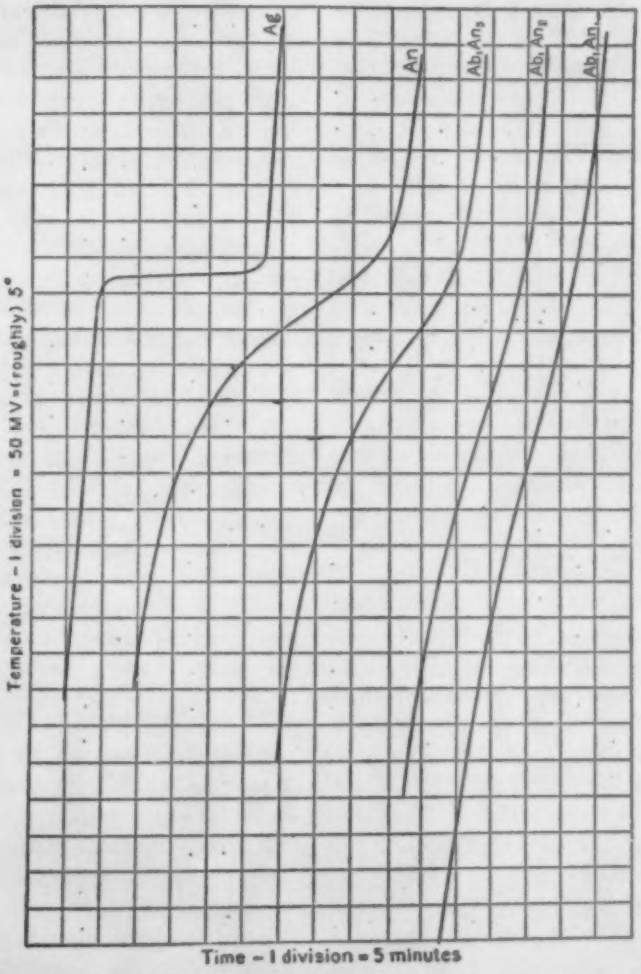


FIG. 2. SUBSTANCES WHICH DO NOT CRYSTALLIZE EASILY

THE STUDY OF MELTING AND FREEZING BY MEANS OF HEATING AND COOLING CURVES. THESE CURVES ARE TYPICAL OF THOSE OBTAINED WITH SILICATES WHICH DO NOT CRYSTALLIZE READILY. A HEATING CURVE WITH SILVER IS INCLUDED.

agree in all essentials with those compositions which have been used for glass from the beginning of its manufacture.

Man has known how to make glass ever since the earliest beginnings of civilization. The farther back the archeologist pushes the curtain of history, the farther back go the beginnings of glass manufacture. Glass was made in quantity by the Egyptians, and during that Golden Age of Egypt, the Eighteenth Dynasty, about 1500 B.C., glass manufacture was a well-established industry, and some of its products were of excellent quality. But it is probable that for the beginning of glass manufacture we must turn to Asia Minor. Beads of glass were plentiful in a cemetery at Ur, dating to 2450 B.C. Possibly the oldest piece of glass ever discovered was found by the 1931–32 expedition of the Oriental Institute of the University of Chicago at Tel Asram, a few miles northeast of Baghdad, dating to 2900 B.C.

From Asia Minor the industry was taken to Egypt, which remained its center until about the beginning of the Christian era. The glass factories of Alexandria were long famous, and from them the industry spread; back to Asia Minor, to China, to Constantinople, to Rome, thence to Germany, France, England and America. The first settlers in Jamestown, in 1607, brought with them workmen and material for establishing a glass factory, and the glass industry was thus the first to be transported to America. But the glass beads of Ur, the cosmetic jars of the queens of the Eighteenth Dynasty, the prized goblets of the Caesars, the beads made at Jamestown for trading with the Indians were all soda-lime glasses, of essentially the same composition as most of our windows and bottles to-day. The reason for this is to be found, not in the lack of enterprise of the glass manufacturer, but in the special requirements which must be met by a successful glass composition. That unique composition and condition of matter known as glass has been the heritage of mankind for five thousand years; but the reason why it is unique came as a by-product of the researches in silicate chemistry of the Geophysical Laboratory.

These reasons may be made clear by considering in some detail the researches which explained them. These dealt with the relations between the crystalline compounds formed of soda, lime and silica, and the liquids obtained by melting these ingredients or compounds. By soda is meant both the raw material used in manufacture, sodium carbonate, Na_2CO_3, which may be introduced either in the hydrated form of "washing soda" or the dehydrated "soda ash"; and sodium oxide, Na_2O, which is left in the glass after the reaction of the sodium carbonate with the silica during melting. By lime is meant both the raw material introduced as whiting or limestone, both calcium carbonate, $CaCO_3$, or burnt lime, CaO; and calcium oxide, CaO, which is left in the glass after reaction with silica during the melting process. The third and largest ingredient, silica, SiO_2, is common sand, whose widespread occurrence and availability in highly pure form at low cost make possible the cheapness of this incomparable material. I shall first discuss the mixture of silica and soda.

Study of Soda and Silica Mixture

Silica is dissolved by molten sodium carbonate, and when all the volatile material has been expelled the resulting mixture contains only sodium oxide, Na_2O, and silica, SiO_2. A large number of such mixtures, of systematically altered proportions of soda and silica, were studied by the quenching method, each at a number of temperatures, until each freezing point has been determined as closely as desired.

To enable the worker to keep track of, and correlate, the numerous experiments,

it is necessary to make a picture or map. In making such a map, the composition of mixtures of two substances is expressed graphically by a straight line, of limited length, whose two ends represent the two constituents (Fig. 3). Intermediate mixtures are represented by intermediate points on the line, and the proportion of the two components in any intermediate mixture is represented by the center of gravity, or balancing point, if the amounts of the two components were suspended from the respective ends. Then temperature can be represented by the vertical distance above this base line, and any point within the diagram will represent a mixture of a given composition at a given temperature.

The diagram (Fig. 3) also tells us just what will be the condition of each mixture at any temperature. The entire diagram is divided into two main portions by a discontinuous line, which represents the boundary between conditions of higher temperature under which the given mixture has all been melted to a liquid, and conditions under which it is partly or wholly frozen into crystals. Each part of the broken line represents compositions from which the same crystalline compound separates on freezing; and over the range of composition shown in Fig. 3 there are three different compounds, each of which possesses distinctive properties.

Compounds of Soda and Silica

On one side is sodium metasilicate, a compound of equal molecular proportions of soda and silica, which melts at 1089°. Sodium metasilicate crystallizes easily, so easily that it can not be obtained as a glass in lots larger than about an ounce. Nevertheless, on cooling it does not freeze promptly, but undercools so much that its freezing temperature can not be determined by the cooling-curve method. The melting point of the pure compound can be determined either by the method of heating curves, or by the method of quenching; but when the composition of the melt from which the compound is freezing is not the same as that of the metasilicate crystals the heating curves become difficult or impossible of

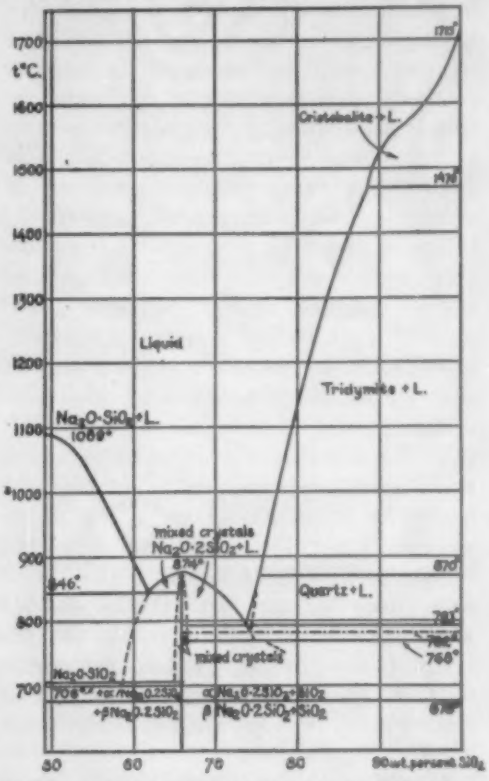


FIG. 3. MIXTURES OF SODA AND SILICA

Diagram showing the freezing points of mixtures of Na_2O and SiO_2 containing more than about 50 per cent. SiO_2. The composition, expressed as percentage by weight of SiO_2, is indicated along the base, and temperature by the distance above the base.

interpretation. Not so the quenching results. If a mixture containing 58 per cent. of SiO_2 is heated above 955°, glass only will be found on quenching; if heated a little below 955°, both glass and crystals will be found; and the nearer to 955° the fewer the crystals. By taking advantage of the tendency of silicates to form glass, the melting point can be determined as closely as desired.

Another compound formed between sodium oxide and silica is sodium disilicate, which is in sharp contrast to the metasilicate in the ease with which it crystallizes. Indeed, glass of this composition had been manufactured in ton lots for years without the compound ever having been obtained, and it remained unknown until our study of the melting relations of these mixtures. The explanation is to be found in the greater viscosity of the liquid at its freezing point. At 1100°, just above the melting point of sodium metasilicate, the viscosity of the liquid is about 14 poises.[1] At the same temperature the viscosity of a liquid of the composition of the disilicate is 550 poises. That 40-fold increase in viscosity at constant temperature is the result of the increased SiO_2-content. But the freezing point of sodium disilicate, 874°, is 215° below that of sodium metasilicate, and at that temperature the viscosity has increased to 26,000 poises. This large viscosity greatly interferes with the molecular rearrangements which must take place to transform the haphazard arrangement of atomic groups in the liquid to the orderly array characteristic of the crystal. Sodium disilicate does not crystallize readily, but cools to a glass.

Consider now the part of the diagram richer in silica. Pure silica, in the form of the mineral cristobalite, melts or freezes at 1713°. As soda is added, the freezing point falls, reaching its lowest value with the mixture containing 26.1 per cent. Na_2O, 73.9 per cent. SiO_2. The addition of a little over 26 per cent. of Na_2O has lowered the freezing point to 793°, a lowering of almost 1,000°. The enormous lowering of the freezing point of silica by alkali oxide is without a parallel. Because of the high content of silica, and the low temperature at the freezing point, the viscosity at the freezing point is about 200,000 poises, and a mixture of this composition invariably cools to a glass. It is exceedingly difficult to crystallize glass of this composition, even by extended heat treatment at the most favorable temperature.

Mixtures of soda and silica intermediate in composition between sodium disilicate and the mixture of lowest freezing point can be obtained as glass in ton lots, but such glasses are not suitable for the ordinary uses to which glass is put because they are soluble in water. The ordinary "water glass" used for a multitude of purposes, such as preserving eggs, as adhesive in the manufacture of corrugated paper and of emery wheels, and for the loading of silk, is prepared by dissolving a sodium silicate glass in water. Its manufacture is a major industry and requires the melting of thousands of tons of sodium silicate glass every year.

Melting Relations of Soda, Lime and Silica

Glass must be resistant to the action of water and weak acid, and something must be added to the sodium silicate to give it such resistance. The substance usually added is lime, CaO, because it gives an excellent product and is cheap. The melting relations of mixtures of the three ingredients, soda, lime and silica, have been determined, and from their study more has been learned about the conditions which make possible the manufacture of glass.

When lime, calcium oxide, is added to the various soda-silica mixtures, new

[1] By the viscosity of a liquid is meant that property by which a moving layer of liquid drags along adjacent layers. It is frequently measured by the tendency toward rotation transmitted through a liquid contained between two concentric cylinders, one of which is rotated. The unit of viscosity is named the poise. Water at its freezing point has a viscosity of about 0.02 poise; at ordinary temperatures, 0.01 poise. At ordinary temperatures olive oil has a viscosity of about one poise, castor oil, about 10 poises; and at 40° F. the viscosity of castor oil is about 33 poises.

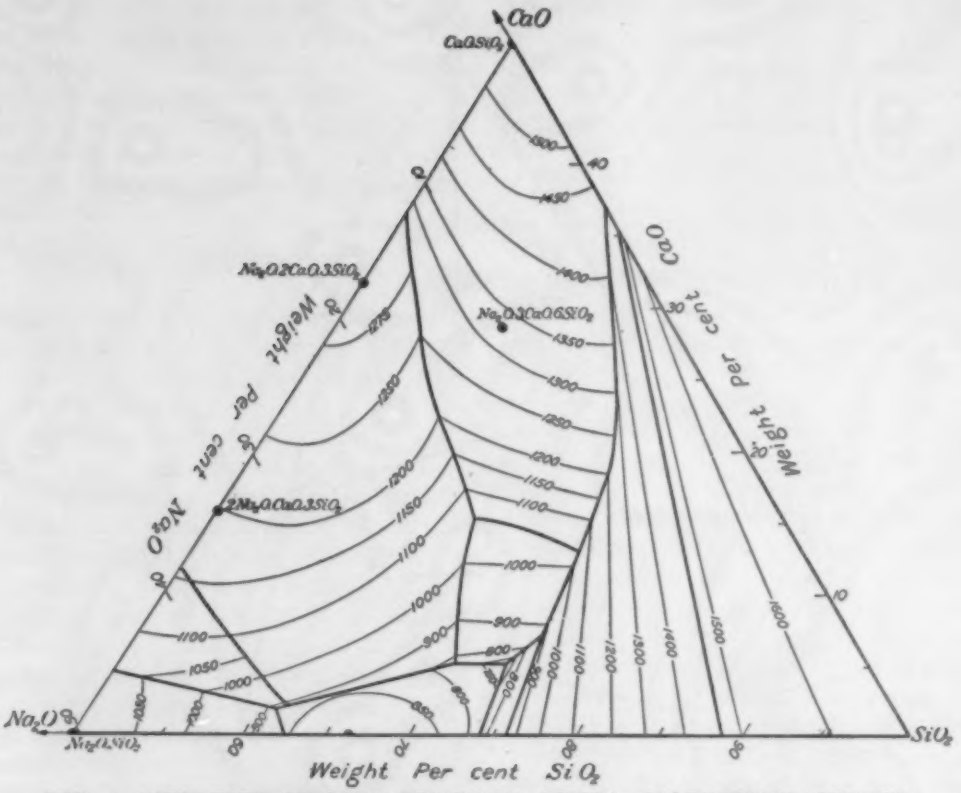


FIG. 4. MIXTURES OF SODA, LIME AND SILICA: ISOTHERMAL CURVES

DIAGRAM SHOWING THE LINES OF CONSTANT FREEZING POINT IN MIXTURES OF Na_2O, CaO AND SiO_2 CONTAINING MORE THAN ABOUT 50 PER CENT. SiO_2. THE ISOTHERMAL CURVES WHICH GIVE THE COMPOSITIONS OF MIXTURES HAVING THE SAME FREEZING POINTS FORM SEVERAL FAMILIES OF CURVES, EACH FAMILY CHARACTERIZED BY THE SAME CRYSTALLINE COMPOUND. THE COMPOSITION REGION THUS OUTLINED IS CALLED THE "FIELD" OF THE COMPOUND.

compounds are formed. Calcium oxide forms with silica a compound, calcium metasilicate,

$$CaO \cdot SiO_2$$

which is found in nature as the mineral wollastonite. With sodium metasilicate, calcium metasilicate forms two compounds,

$$2Na_2O \cdot CaO \cdot 3SiO_2$$

and

$$Na_2O \cdot 2CaO \cdot 3SiO_2.$$

These compounds are shown in Figs. 4 and 5, diagrams which show the melting relations of mixtures of the three ingredients, just as Fig. 3 shows those of the two components, soda and silica. The base line represents mixtures of sodium metasilicate,

$$Na_2O \cdot SiO_2,$$

and silica; the right-hand side, of calcium metasilicate,

$$CaO \cdot SiO_2$$

and silica; and the left side, of sodium metasilicate and calcium metasilicate. Fig. 4 shows clearly the compositions of the compounds and the composition regions from which they separate as crystals when the melt is cooled. For example, the compositions of the two metasilicate compounds,

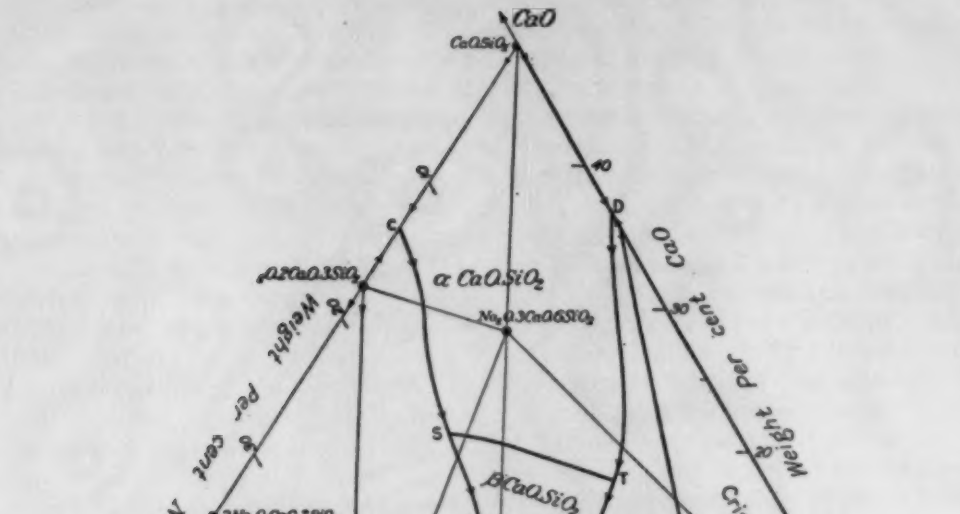


FIG. 5. MIXTURES OF SODA, LIME AND SILICA: BOUNDARY CURVES

DIAGRAM SHOWING THE BOUNDARIES BETWEEN THE FIELDS OF THE VARIOUS COMPOUNDS FORMED FROM MIXTURES OF Na_2O, CaO AND SiO_2 CONTAINING MORE THAN ABOUT 50 PER CENT. SiO_2. THE ARROWS ON THE BOUNDARIES BETWEEN THE FIELDS INDICATE FALLING TEMPERATURES.

$$2Na_2O \cdot CaO \cdot 3SiO_2$$

and

$$Na_2O \cdot 2CaO \cdot 3SiO_2,$$

are shown on the side

$$Na_2O \cdot SiO_2\text{-}CaO \cdot SiO_2;$$

their respective fields (Fig. 5) are *ABLK* and *BCSRNML*.

Mixtures of calcium and sodium metasilicates are not suitable for glass manufacture because they pass so readily into the crystalline condition that they can not be made on a manufacturing scale, although they can be made in small quantity. Also, when they are rich in sodium metasilicate they are too susceptible to attack by water. This is true of all mixtures which lie to the left of the line joining

$$Na_2O \cdot 2SiO_2$$

with

$$Na_2O \cdot 2CaO \cdot 3SiO_2,$$

and these mixtures will not be further considered. To obtain a resistant glass more silica must be added, and such addition lowers the melting point.

When more silica was added to sodium metasilicate a compound, sodium disilicate, was formed, which has a low melting point, and is readily obtained as glass. No such compound is formed with calcium metasilicate, which melts at 1540°. Also, the lowest melting mixture of lime and silica melts at a high tem-

perature, 1436°, and crystallizes readily. Sodium silicate must be added. When the sodium silicate added to calcium metasilicate is sodium disilicate, or a sodium silicate mixture containing a larger proportion of silica, a new compound makes its appearance. This compound has the composition

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

and, because of its important part in the crystallization or devitrification of the ordinary soda-lime glass, it has been named "devitrite."

The composition of devitrite is such that it may be regarded as made up of calcium metasilicate and the lowest melting mixture of soda and silica. It has characteristic properties which help to explain the formation of glass. When the pure compound is heated, it does not remain homogeneous until its melting point is reached, then melt to form a liquid of the same composition as the crystals. Instead, it begins to melt at a much lower temperature, 1060°, with formation of crystals of wollastonite and a liquid containing much more sodium silicate. This liquid is on the line *RQ* of Fig. 5. Because of this peculiar type of melting it follows that the melts from which devitrite crystallizes, shown in the area *NRQPO* of Fig. 5, are richer in sodium silicate, and they are low melting liquids. They melt lower than any other mixtures of the three components; and the lowest melting of all is that represented by the point *O*, 725°. They are very different in composition from the crystals which should separate; and to form these crystals there must be much molecular movement. But the glass at point *O* has the enormous viscosity of 9,000,000 poises, consequently molecular movement is slow and crystallization ordinarily does not take place. Every composition within the devitrite field is a possible commercial glass composition, and most commercial glasses are within this composition range, in so far as they are pure soda-lime glasses.

We have seen, then, that the region of commercial glass compositions is essentially that of the compound,

$$Na_2O \cdot 3CaO \cdot 6SiO_2,$$

and that the temperatures in this region range from 1060° to 725°, and we have the answer to why glass behaves like glass. Mixtures within this area are above their freezing temperatures throughout their working range. Glass must be subjected to various shaping operations while in a not too viscous condition, and if the freezing point is within the temperature range within which it must be worked, crystallization is almost certain. But because of their low freezing points, glasses in this area become viscous enough for working while still too hot to freeze, and by the time the freezing point is reached the glass is so viscous that crystallization can be induced only by special heat treatment. But let the composition depart only a few per cent. from a restricted field, and this is no longer true. As soon as the glass enters the field of silica, of calcium metasilicate or of

$$Na_2O \cdot 2CaO \cdot 3SiO_2,$$

the temperature increases rapidly and crystallization takes place much more readily. Hence the glassmaker must keep his compositions within narrow limits.

He is aided, however, by another factor; he is never working with pure soda-lime glasses, even though he may call them such, but always with glasses containing significant amounts of other constituents, which are introduced incidentally either as impurities, in the ingredients, or of the containers in which they are melted or which are introduced deliberately. The effect of each of these impurities is to lower the melting point. For example, replacement of one per

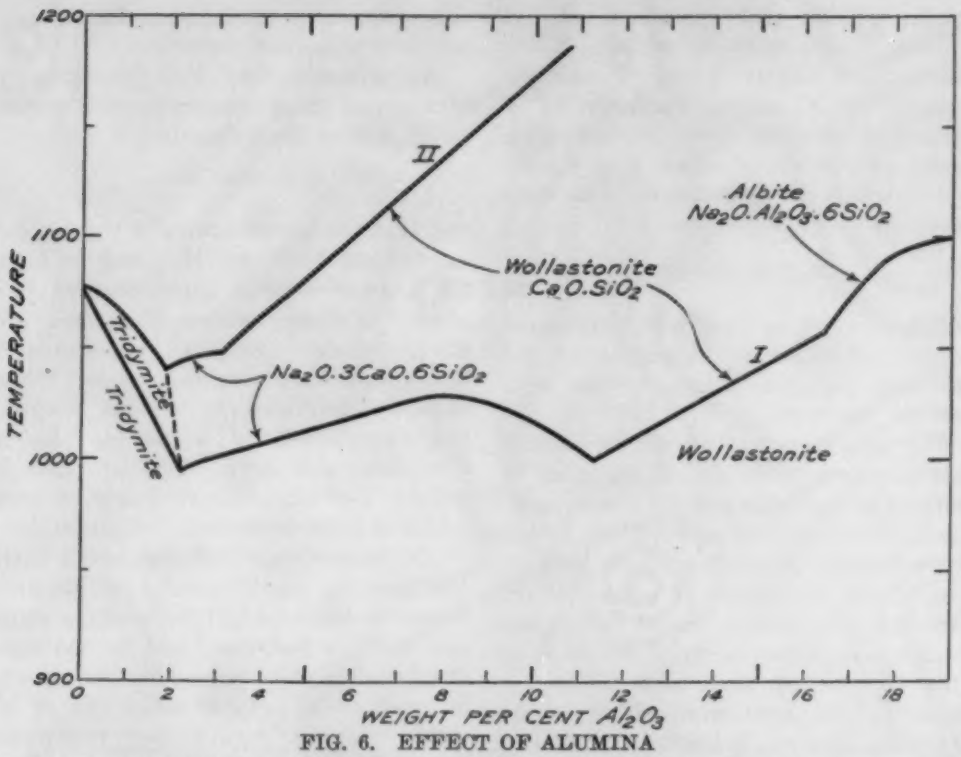


FIG. 6. EFFECT OF ALUMINA

THE EFFECT OF ALUMINA ON THE FREEZING TEMPERATURE OF A SODA-LIME-SILICA GLASS CONTAINING 11 PER CENT. CaO AND 74.7 PER CENT. SiO_2. CURVE I SHOWS THE EFFECT OF REPLACING LIME BY ALUMINA, AND CURVE II THE EFFECT OF ADDING ALUMINA TO THE GLASS.

cent. of lime by alumina lowers the melting point almost 100° (Fig. 6).

The story of the discovery of the advantage to be gained by the addition of alumina is an interesting one. Back in the eighties it was a matter of common knowledge that glass made in the Thuringian Forest was superior for glass-blowing, because under treatment which would devitrify an ordinary soda-lime glass it remained clear and transparent, and the difference was ascribed to some secret formula. But an investigation showed that the sand used contained almost 4 per cent. of alumina and that addition of alumina to the usual batches greatly improved the product. We can explain this now: the alumina lowered the melting point and brought the glass into the field of the

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

compound, which is characterized by small tendency toward crystallization.

The effect of other oxides which may be considered as accidental impurities is similar. Some magnesia, MgO, is usually present, if only as the result of corrosion of the clay container in which the glass is melted, but small amounts of magnesia have a favorable effect in lowering the liquidus temperature (Fig. 7). In the United States it is a common practice to introduce magnesia by the use of dolomitic limestone. Iron oxide has a marked effect in lowering the freezing point, and it was present in most of the older glassware, in amounts which would not be tolerated to-day, except when the color it gives is definitely wanted. Boric oxide is often added, to increase the speed of melting, the chemical durability, the brilliance

and the strength. It has a favorable effect in lowering the melting temperature.

Many glasses contain part or all of their alkali as potash, K_2O, but its use is limited by its higher cost. The glasses formed are more difficult to crystallize than the soda glasses, which circumstance is probably to be ascribed largely to the greater viscosity of the potash glasses, although the larger number of dissociating compounds, with consequent increasing molecular complexity, undoubtedly plays an important part. The "Bohemian" glass used for combustion tubing, which must withstand a high temperature, is a potash glass. The addition of potash to a soda glass diminishes the tendency toward devitrification, increases the viscosity and renders the glass more resistant to weathering.

Types of Manufactured Glass

Most of the glass manufactured is essentially of the soda-lime-silica type, modified by the inclusion of small percentages of other oxides; and the major uses to which glass is put, including windows, automobile glazing, bottles, jars, table ware and electric light bulbs, take a glass of this type. The various types of glass used for chemical ware and laboratory tubing were formerly exclusively from this same type. The ordinary "soft" glass was a soda-lime glass, the inferior grades tending to be low in lime, high in soda, which placed them rather near the lower portion of the

$$Na_2O \cdot 2CaO \cdot 3SiO_2$$

field, and containing little alumina. The better grades contained Al_2O_3 and were nearer the boundary between

$$Na_2O \cdot 3CaO \cdot 6SiO_2$$

and silica. From this the composition ranged from those which were improved by the inclusion of some MgO, K_2O, B_2O_3 or zinc oxide, ZnO, to those, such as the Jena Geräte, in which all these oxides were present. All these types are to be considered as derived from the ordinary soda-lime composition by the addition and substitution of different oxides for the purpose of securing greater resistance to weathering, and a lowered freezing temperature.

These older types of chemical ware have been largely superseded by Pyrex resistant glass, which is of a different type, not to be regarded as derived from the ordinary soda-lime glass. Rather, it is a glass in which the melting point of the silica is lowered by the addition of boric oxide, B_2O_3, and, in smaller amount, alumina, Al_2O_3, with only the smallest possible amount of alkali. It is intrinsically superior to corrosion and to breakage from heat shock, but is more difficult to manufacture and work.

The 200-inch telescope could not have been made if such a superior glass were not available. The protracted heat treatment necessary to cool that enormous mass of glass without introducing strains

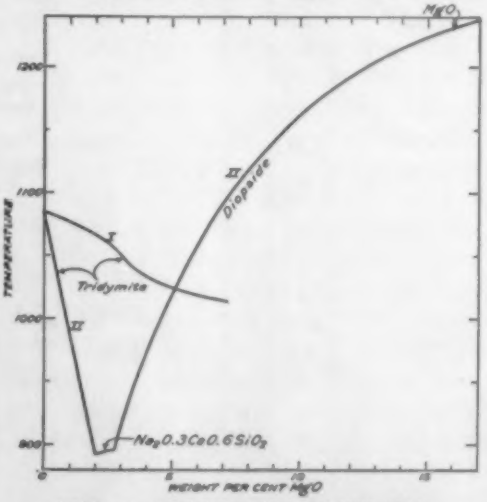


FIG. 7. EFFECT OF MAGNESIA

THE EFFECT OF MAGNESIA ON THE FREEZING TEMPERATURE OF A SODA-LIME-SILICA GLASS CONTAINING 11 PER CENT. CaO AND 74.7 PER CENT. SiO_2. CURVE I SHOWS THE EFFECT OF REPLACING LIME BY MAGNESIA, AND CURVE II THE EFFECT OF ADDING MAGNESIA TO THE GLASS.

PERCENTAGE COMPOSITION OF SOME REPRESENTATIVE GLASSES

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Silica	SiO_2	67.82	63.86	65.03	65.95	68.0	74.16	72.5	72.68	71.76	64.7	66.90	79.57	80.75	70.4	71.34	34.5	59.3	45.64	28.4	75.52
Boric oxide	B_2O_3										10.9	7.22		12.00	7.4		10.1				
Sodium oxide	Na_2O	13.71	22.66	17.37	20.30	22.0	15.08	15.9	13.17	12.65	7.5	1.25	0.66	4.10	5.3	13.42		5.0	1.77		3.92
Potassium oxide ...	K_2O	2.31	0.80	1.68	0.96			0.5			0.37	2.40	11.60	0.10	14.5	0.10		8.0	8.66	2.5	3.63
Calcium oxide	CaO	4.03	7.86	5.65	6.89	7.2	4.64	4.9	12.95	11.55	0.63	7.94	7.80	0.30	2.0	12.51			0.50		0.78
Magnesium oxide ..	MgO	2.30	4.18	2.52	1.37		3.41	3.5		2.41	0.21	0.61	0.11								0.10
Barium oxide	BaO											7.27					42.0				
Zinc oxide	ZnO										10.9						7.8				
Lead oxide	PbO			0.19														27.5	43.45	69.0	
Alumina	Al_2O_3	4.38	0.65	2.13	2.49	3.1	1.25	1.6	0.50	0.82	4.2	6.38	0.32	2.20		0.09	5.0		0.03		14.11
Ferric oxide	Fe_2O_3	1.08	0.67	0.97	0.28				0.07	0.10	0.25	0.22	0.04								1.74
Sulfur trioxide	SO_3	0.98		1.70	1.08				0.44	0.47											
Manganese oxide ..	Mn_2O_3	1.12	trace	0.65	0.97						0.01				0.1		0.1				

1. Egyptian glass from Thebes, about 1500 B.C. Opaque, dark blue, also contains 1.96 per cent. copper oxide, CuO.
2. Egyptian glass from Tell el Amarna, about 1400 B.C. Opaque, dark colored.
3. Assyrian-Babylonian glass from Nippur, about 1400 B.C. Dark blue. Also contains 1.94 per cent. copper oxide, CuO, and 0.93 per cent. cobalt oxide, CoO. This is the only known occurrence of cobalt oxide in antique glass.
4. Egyptian glass from Elephantine, about 100 B.C. colorless.
5. Inferior glass made for Christmas tree ornaments.
6. Bottle glass.
7. Electric light bulb glass.
8. Polished plate glass.
9. Modern window glass.
10. Laboratory glass, Jena Geräte. Also contains 0.14 per cent. arsenic oxide As_2O_3.
11. Laboratory glass, Jena combustion.
12. Laboratory glass, Kavalier.
13. Laboratory glass, Pyrex chemical resistant.
14. Optical glass, borosilicate crown. Also contains 0.2 per cent. As_2O_3.
15. Optical glass, spectacle crown. Also contains 0.9 per cent., As_2O_3.
16. Optical glass, dense barium crown. Also contains 0.5 per cent., As_2O_3.
17. Optical glass, light flint. Practically this same glass is used for heavy cut glass, for some tubing, and some electric light bulbs. Also contains 0.2 per cent. As_2O_3.
18. Optical glass, medium flint. Also contains 0.22 per cent. As_2O_3.
19. Optical glass. Extra dense flint. Also contains 0.1 per cent. As_2O_3.
20. Obsidian glass from Obsidian Cliff, Yellowstone National Park. Also contains 0.08 per cent. FeO.

from unequal heat distribution would inevitably have devitrified an ordinary glass. The improved Pyrex used is especially resistant to devitrification, and the success of the Corning Glass Works in making this great disk is in part due to the superior glass which they developed for the purpose.

The optical glasses are a group important in their use in instruments but insignificant in their tonnage and total commercial value. They are all derived essentially from the same general type. Many optical glasses of the crown type are essentially the same as ordinary window glass, except that they possess the quality characteristic of all optical glasses of a physical perfection resulting from freedom from bubbles and inhomogeneity. Other similar glasses contain notable quantities of K_2O replacing Na_2O, and of B_2O_3 replacing SiO_2, in quantity up to, and sometimes exceeding, 10 per cent., giving rise to the borosilicate crowns.

An important series of glasses are the optical "flints," which contain lead oxide, PbO. They range from light flints containing 25 to 30 per cent. of PbO, and essentially the same as the lead glass formerly extensively used for blowpipe work, for lamp bulbs and for cut glass, up to extra dense flints containing as high as 80 per cent. of PbO. The optical flints usually contain K_2O as the only alkali.

Another important group of optical glasses are the barium crowns, characterized by the presence of barium oxide, BaO, in place of lime, but still essentially of the same general composition, and owing their important qualities to the high molecular weight of barium oxide. The optical glasses are for special purposes, and as a class are not suitable for most of the uses to which glass is put, by reason of too great susceptibility to weathering, difficulty in manufacture or high cost.

Non-Commercial Types

Those compositions which have been hit on for commercial glasses have the common characteristic that they exhibit a great reluctance to pass from the liquid to a crystalline condition even under the most favorable circumstances, a characteristic possessed in a less or even in a greater degree by many substances wholly unsuitable for practical use. Many organic substances fall in this category, of which glucose solutions may be taken as example. Beryllium fluoride can be obtained as glass. Alum and some complex sulfates can be quenched to the glassy form. Phosphates are well-known glass formers, and, indeed, the so-called meta- and pyrophosphoric acids are known only in the glassy condition. Boric oxide, B_2O_3, has never been obtained in any but the glassy condition. None of these is suitable for commercial uses because they are too easily decomposed by water.

Glass made from silica itself possesses in the highest degree the necessary properties of freedom from devitrification and resistance to weathering, and if it were not so difficult to melt it would be the most suitable material for most of the uses to which glass is put. The melting point of the high temperature form of silica is 1713°, and at its melting point it is so exceedingly viscous that special and expensive treatment is necessary to free it from bubbles and obtain a clear transparent glass. The resulting cost of manufacture is prohibitive, and other oxides must be added to lower the melting point and viscosity. In addition there are some uses in which the modification of properties obtained by the incorporation of other oxides is essential.

Natural silicate glasses are known, most of which can be grouped under the term obsidian. The obsidian cliffs of Yellowstone Park are enormous masses

of this volcanic glass, and it is widely distributed over the surface of the earth. It was highly prized by people of Stone Age culture, and worked by chipping into axes, spear and arrow heads and even into knives and razors. In composition it may be considered as a mixture of alkali feldspar and silica, and in the Laboratory we have studied such mixtures.

The alkali feldspars differ in composition from ordinary glass chiefly in their containing alumina instead of lime. The soda feldspar, albite, has the composition,

$$Na_2O \cdot Al_2O_3 \cdot 6SiO_2;$$

and if the alumina were replaced by lime, giving Na_2O, CaO, $6SiO_2$, the resulting composition would be near the most favorable glass field. But natural obsidian can not be imitated by the glass manufacturer, and the alkali feldspar glasses are not suitable for commercial glass, because of their enormous viscosity. The soda feldspar, albite, has a true melting point at 1122°, and the potash feldspar, orthoclase, melts with decomposition at 1170°. But at 1200° the albite glass has a viscosity of 10 million poises, and orthoclase glass a viscosity of 300 million poises. It is necessary that a successful glass composition be fluid enough to melt readily at a temperature accessible in industrial practice.

The feldspar glasses will not crystallize, but other mineral glasses we have made in the Laboratory crystallize too readily. They can only be obtained by the quenching method and thus are not suitable for commercial glass. Indeed, of the whole range of possible silicate compositions, the only mixtures which are fluid enough at an industrially accessible temperature to be melted on a commercial scale, viscous enough to be worked at a temperature above their freezing points, and so viscous at their freezing points that they can not devitrify, are those soda-lime-silica glasses in and near the field of the compound,

$$Na_2O \cdot 3CaO \cdot 6SiO_2,$$

the compositions which always have been used for commercial glass.

Summary

That unique composition of matter which is commercial glass has been known to mankind for at least five thousand years. For these many centuries man has made glass. Its manufacture first was a primitive art. Then it became an industry, an industry which was a small-scale personal triumph of a skilled craftsman working with miserable equipment and bound by the spell of tradition. Now it is a mighty mechanized industry, controlled by applied scientific knowledge. But the reason why this composition of matter is the only one possible for a commercial glass remained a mystery throughout the centuries until it was discovered by the Geophysical Laboratory as an incidental by-product of its researches on the chemistry of the silicates.

PRISONERS OF DARKNESS

By Dr. STANTON C. CRAWFORD

PROFESSOR OF BIOLOGY, UNIVERSITY OF PITTSBURGH

ANIMALS that live most of their active lives in the darkness of night and shun the light seem to be prisoners of that darkness in a very real sense. Some bond holds them within the shadows. Striking examples are afforded by termites, woodboring beetles, deer-mice and opossums. In addition to the citizens of night there are those of dawn and dusk, which inhabit a zone of half light. Insects accustomed to appear at a certain time as twilight falls may appear earlier than usual on cloudy evenings. Such instances could be recounted in great number.

An apparent explanation of these habits is that the various animals seem to be attuned to certain ranges of intensity of light. For each species there is an optimum light range, which the members of the group seek as a setting for the normal activities of life. The degree of intensity is supposedly determined by the visual sense. Thus, most butterflies are attuned to a higher intensity of light than are many moths. Bright sunlight attracts the one, repels the other. The tawny Monarch flits over the meadows, visiting milkweed blossoms, or floats high over city streets, while the nocturnal moth clings to the bark of a shaded treetrunk, which it often closely resembles. But let darkness fall, and the butterfly hangs motionless on a leaf. The weak flame of a candle, so dim a light as not to stimulate the butterfly at all, serves as an irresistible and fatal attraction to the moth. Light traps are now employed to catch such orchard pests as codling moths, bud moths, leaf-rollers, cutworm moths and other insects. The flight of the moth toward the lamp is so nearly automatic that it can not save itself. Nature provides no protection for such situations, because the natural lights which the insect would encounter at night, those of the heavenly bodies and reflections of the same from earthly objects, afford no possibility of harm.

The moth of nocturnal species lives a life of oblivion in comparison with his brilliant and conspicuous relatives which are admired in the brightness of sunlight. Some beautifully colored moths seldom would be seen by man were they not drawn from the cool black shadows to the unnatural glow of artificial lights. Within closely related groups of moths there are delicately graded degrees of sensitivity to light. In the American silkworm group, Phil and Nellie Rau report that *Cecropias* fly during the hour just before and at dawn, while *Cynthia* and *Polyphemus* moths fly before midnight as well as at dawn. *Prometheas* on the other hand fly in the late afternoon.

Other conditions, such as increased humidity, lowered air temperature, reduced air motion and decreased rate of evaporation, are characteristic of the night, and these items have great importance for living things. Nevertheless, at least for the vertebrates, the absence of light looms as the most significant factor of the nocturnal environment.

Animals which from conscious or unconscious beginnings have now arrived at a nocturnal or crepuscular habit undoubtedly find advantage in carrying on the more active phases of existence under cover of darkness or in dim light. The

more likely explanations that present themselves to man's mind may or may not constitute sufficient reasons for the adoption of the nocturnal habit. Further, it would not be supposed that, except in the higher mammals, the night time is consciously chosen on account of any of these advantages. It might be considered that these benefits associated with nocturnal living were factors that in some way and over a long period of time caused various races to avoid light. Now inherent in these forms of life, the propensity for nocturnal activity expresses itself when the favored environmental factors recur in nightly rhythm.

The most evident advantages of the nocturnal habit are four. First might be named the avoidance of natural enemies that are active in daylight. Harvestmen, spiders, millipedes, crickets, roaches, moths and ants would in many instances be sought as food during the day by birds and reptiles as well as by insectivorous mammals. Toads and frogs would be eaten by snakes, by such birds as herons and hawks and by some mammals. Rats and mice would find many enemies among mammals, birds and reptiles. Bats would be pounced upon by hawks.

This avoidance of enemies also seems of possible advantage in the case of animals popularly supposed to be protected by concealing and imitative color or configuration, which nevertheless would form part of the diet of daytime animals. The walking-sticks and mantids, which in outline, texture and coloration so closely resemble leaves and twigs, do not always escape the notice of day birds.

Further, there is greater safety at night for the feeding of herbivorous animals. Thus, there are the fruitbats, great Chiropterans with a wing-spread of two or three feet, which hang themselves up to feed on tropical fruits. Porcupines, beavers and rabbits feed in comparative safety. Agoutis feed on fallen nuts and fruits at night. Defenseless, they depend on the darkness for concealment and on speed for escape. The capybara, a huge guinea pig several feet in length, feeds on swamp plants along the Brazilian river banks after dusk. To their respective streams also come the bush cow or tapir, the elephant and rhinoceros. The deer and other grazing animals can feed unseen at night, keeping the head down with comparative safety. Animals engaged in such feeding activities would be especially vulnerable to their natural enemies in daylight.

A second advantage would seem to be afforded through easier location and acquirement of the preferred food at night. This benefit may be ascribed variously to the invisibility of the hunter, the plentifulness at night of the intended food animals or the greater ease of detecting victims by the sense of smell. Odors remain longer in the air at night, due to greater humidity and the relative absence of upward air currents. Further, if the prospective victims are themselves typical daytime forms, they are more subject to attack at night on account of sleep or its equivalent or their poorer adaptation for successful nocturnal activity. This advantage for the nocturnal hunter may be realized by carnivorous animals such as the scorpions, tarantulas, spiders, sluggish snakes, owls, goatsuckers, raccoons and cats. Also, scavengers and general feeders may be able to seek food with more ease at night, due to better conditions for the use of the olfactory sense. Beetles, millipedes, roaches and the vertebrate opossums, kinkajous and armadillos, for example, might be considered as coming under this heading.

Successful avoidance of evaporation from the body surface may be named as a third advantage. Animals that on

account of the nature of their external covering would suffer from excessive evaporation through daytime activity, and would conceivably benefit from the nocturnal habit include earthworms, snails, cockroaches, mosquitoes, termites, salamanders, toads and treefrogs. Park and his colleagues reported that many insects of Ohio forests increase nocturnal activity with increase of relative humidity, decrease of air temperature and rate of evaporation.

A last major advantage is doubtless found in better conditions for communication at night. Sounds produced have less competition, odors travel farther and are apparently stronger in the damp air. Light-producing organs are of value at night and useless by day.

Some animals seem to benefit in two or three of these ways. In any one species, the reasons applicable can only be conjectured. Not all those active at night can be seriously placed under any heading. Thus the fact that the longhorn grasshoppers are in some species nocturnal, in some day-living, while practically all are apparently protectively colored and all live in the same general environment is difficult to explain. Along with almost any species active at night for any apparent reason can be found a closely related form not active at night, yet exposed to the same conditions of life. The problem is hence a very complex one, inviting extensive and detailed study.

When we seek to determine the adaptations exhibited by groups active at night, we encounter much uncertainty. Such differences in sense organs as exist between nocturnal and daytime forms of close relationship are differences of degree rather than of kind. There are a few definite adaptations in the way of light, sound and scent production. Nevertheless, with the possible exceptions of luminescence and some features of vision, there is observed no modification which might not be fully as useful by day as by night. Our judgment is that the extreme development of some of these specializations of form and function is not so necessary for successful living by day. The species named might be capable of successful nocturnal existence without any or all of the supposedly appropriate modifications which they exhibit. The crucial point of development of each sense necessary for the successful nocturnal activity of a given animal species would be very difficult to determine, especially since the senses are not employed singly so often as collectively.

Further, it would be difficult to list the various senses in the order of their relative usefulness at night. The sense of smell is probably of greatest importance, and that of sight might be named last, but undoubtedly this arrangement would be questioned. It must be remembered that our ideas in regard to the sensations of animals other than ourselves, of invertebrates particularly, are only inferences from our own sensory experiences. It is likely that they are often inadequate and erroneous. We can never be sure that lower animals experience sensations in the same way that we do, even though perceptory organs of seeming adequacy are known to exist. However, a number of generalizations may be made about these sensory functions.

The sense of smell may be suspected of having at least four uses at night. First, it assists in the congregating of individuals of the same species and in following trails. Invertebrates employing the sense for these purposes include along with others the termites and ants, among which the activity of the whole colony is apparently directed chiefly by scent and odor. Vertebrates that could be named in this connection are opossums, muskrats, beavers, raccoons, cats,

porcupines, armadillos, bears and deer. It has been suggested that the oil from the preen gland of birds when spread on the feathers may aid in recognition of individuals amid the darkness of night or the shadows of dense plant growth.

Secondly, this olfactory sense functions in sex attraction, by means of "alluring glands." Females of many species of moths and beetles emit an odor that attracts the males, often in large numbers. The vertebrate alligators, cats, peccaries and deer along with many others would come in this category.

Thirdly, this sense functions in the location of food. Animals in which the olfactory sense is depended upon heavily for this purpose are the roaches, beetles, moths, mosquitoes and ants; armadillos, porcupines, raccoons, cats, bears, foxes, weasels, mice, rats, opossums, and of course many others.

Fourthly, it functions in the detection of enemies and friends. This is apparently an important use of the sense in such vertebrate forms as the bear, deer, antelope and tapir, and many invertebrate groups.

The sense of taste, which is closely associated with the olfactory sense, is very generally developed throughout the groups of non-aquatic invertebrates. No greater development of this sense would be expected in nocturnal animals than in their daytime relatives. Perhaps our ideas on this point do not coincide with the actual situation, however, since the sense is so much more highly developed in ants, flies, etc., than in ourselves, and hence perhaps much more significant in their lives than in ours. In various insects, organs of taste have been located on antennal and leg surfaces. Such equipment would seem to give the sense special usefulness at night for finding and inspecting food, if species possessing such structures are active in the dark. Organs of taste certainly have large usefulness at night for inspecting food that can not be seen.

Perhaps the main distinction between the senses of smell and taste is that if the end organs actually come in contact with the food they are to be considered gustatory; if they do not, they are to be considered olfactory. Both of these senses, when resident in antennal structures, are closely associated with that of touch. There would thus be a contact-chemical sense of unified character. Nocturnal insects, which obviously have delicate antennae on which they depend heavily for sensory experience, include centipedes, crickets, walking-sticks, roaches, termites and ants. They are probably just as important in other insects whose antennal equipment is not so apparently depended upon.

Organs of touch are of value at night in moving about, in inspecting food or other objects encountered and in perceiving vibrations. This last faculty passes into that of hearing. Among the invertebrates many sensitive and elaborate organs of touch are found. Delicate tactile hairs are a device frequently employed. Among the vertebrates, aside from the general sensitivity of the skin, we find such special developments as the "whiskers" of rodents and various other mammals, the delicate muzzle of the deer and the very sensitive organs of the nose and wings of the bat. The facial pits of the pit-vipers are reported to function in the perception of air vibrations. All these structures are devices for stimulating nerve terminations.

Closely associated with the tactile sense is sensitivity to temperature. Temperature affects the degree of activity of many animals which are abroad at night, functioning in correlation with humidity and air motion. Insects, with a large surface-to-volume ratio, have a special problem with reference to temperature changes.

The sense of hearing is closely allied to

that of touch, particularly among the invertebrates. Sound production and reception is often a major means of communication between members of the same species at night as well as by day, and is important in the detection of approaching enemies or victims, as the case may be. Sound-making serves to frighten away enemies, to warn others of their approach, to attract and woo mates, to communicate items of information. Animals which apparently depend at least in part on this sense for communication at night include grasshoppers, crickets, some ants, mosquitoes and some beetles; along with the vertebrate frogs, tree-frogs, alligators, owls, goatsuckers, bats, shrews, mice, foxes, coyotes, howler monkeys, beavers, cats and a legion of others.

It must be remembered that many sounds are produced and heard by other animals that we can not hear, because they are too high or too low in pitch. This is especially true in the insect realm. Further, the kind of sound to which the human mind adjusts itself differs from that which is most significant to the animal. Man is rather little interested in the sounds which the things themselves produce and which are meaningful for the animal. The sounds which most often concern man are the sounds of organized speech which merely refer to objects and happenings.

Light production and the sense of sight have an obvious relationship at night. Light is produced by the fireflies and elater beetles and their larvae, by some other insects and by a number of other animals. This phenomenon is really of wider occurrence than is usually realized.

The photogenic organs of fireflies consist of granular cells enclosed in a network of fine air-carrying tubules or tracheae. These cells have the power of secreting a substance which is luminous when acted upon by oxygen from the tracheae in the presence of moisture. Fundamentally, this effect seems to depend upon a luciferin-luciferase reaction. The mass of branching air-tubes or tracheae makes possible rapid oxygenation and the resulting short quick flash of the fireflies. The rate of flash may be modified by temperature and also seems to be subject to direct nervous control. Light production is sometimes considered as simply a by-product of metabolism. Occasional synchronous flashing of fireflies in a given area, and the employment of flashing in mating behavior indicate that the light produced by one individual is perceived by others and that they are influenced by it.

Among various animals the light produced ranges from green to various shades of red, purple and violet. In some species, several colors or shades are emitted by the same organ at different times or by different organs on the same individual. According to Harvey, light is produced by species in almost forty orders of animals, chiefly marine. The jelly-fish and Portuguese-man-of-war, among the Coelenterates, and the Protozoan *Noctiluca* are familiar to any one who has cruised warm seas at night. Less familiar are luminous marine worms, brittle-stars, corals, squids and various other mollusks. Many of the deep-sea fish have batteries of luminescent organs, in line from head to tail, outlining eye and mouth, decorating fins and feelers. They live in constant darkness, in the cold depths where the sun's visible rays can not penetrate. Among these forms blue and green are colors of light commonly displayed. In general, it may be said that among animals the production of light is probably never necessary, even if occasionally useful. Probably it is all visible light, and it is produced apparently without the liberation of any heat.

In considering the possible uses of photogenic organs to the animals which possess them the following ideas suggest themselves. The congregating of individuals may be assisted by light production. Where the luminous organs have a definite pattern, as in certain fishes, recognition of individuals may be facilitated. Perhaps enemies are frightened away by light produced unexpectedly, through the action of organs under nervous control. The luminous "eyes" of some adult click-beetles are thought by some persons to be of "horrifying" intent. Again, the light may conceivably serve as a lamp, enabling deep-sea animals to find their way about. Or the light may be used as bait to attract prey. Thus the "fishing frog," a deep-sea fish, has a luminous pendant on the end of a fishing-pole arrangement projecting in front of its cavernous mouth. Small fry venturing near to investigate would certainly be in danger of immediate engulfment. As already noted, the rate of flash in the fireflies and glow-worms is reported to have a part in sex attraction. Some fish are said to be luminous only during the breeding season.

From a broader standpoint, it can be said that the influence of light is quite marked in most animal forms. Daytime insects accustomed to sleep at night are less active or quiescent on cloudy days. Moonlight tends to enliven daytime forms at night. Thus we have the calling of day birds and the voicing of some typically daytime mammals at night. The attraction of insects to artificial lights at night is a familiar phenomenon.

Opportunity for the employment of the sense of sight at night is quite limited in comparison with its daytime usefulness. However, some animals can apparently see quite well, even when starlight only is available. Frequently nocturnal animals possess eyes equipped with a reflecting tapetum behind the visual cells, by means of which faint light rays are caused to pass back through the retina a second time. Nocturnal vertebrates tend to have relatively large eyes. That eyes are subject to light adaptation is further testified by the fact that well-established cave animals usually have degenerate eyes or are eyeless.

Such an analysis still leaves much of a feeling of mystery about the lives of animals displaying the nocturnal habit. They seem to belong to another world, and it is a realm that entices fancy and challenges interest. More definite knowledge would probably not lessen our interest in the lives of creatures whose accustomed sphere of activity is so different from our own.

THE COURTSHIP DISPLAY OF THE FLIGHTLESS CORMORANT[1]

By MALCOLM DAVIS and HERBERT FRIEDMANN
NATIONAL ZOOLOGICAL PARK—UNITED STATES NATIONAL MUSEUM

In the spring of 1934 we observed a pair of flightless cormorants, *Nannopterum harrisi* (Rothschild), members of the bird collection at the National Zoological Park at Washington, D. C., indulging in a series of what seemed on casual glance to be "queer" maneuvers. On closer observation during 1934 and 1935 these grotesque movements appeared to take the form of a courtship display. Inasmuch as the literature, as far as we have been able to determine,

[1] Published by permission of the Secretary of the Smithsonian Institution.

does not reveal any account of these peculiar posturings, we have prepared the present description.

The pair of birds occupy an outside, moat-enclosed, barless cage that has in its center a sizable little artificial pond. Here the pair has remained out of doors during even the coldest weather that Washington experienced in the winter, 1934–35. Although normally birds of equatorial waters, they were adaptable enough to adjust themselves and to thrive under temperature conditions very different from those of their native habitat.

Courtship began early in the spring, in the first warm days of March, and continued with undiminished frequency through the spring and early summer months, gradually becoming more restricted to the morning hours late in August and terminating in early October. At first there seemed to be no definite time of day for displaying, but the birds indulged in it on and off at intervals of twenty minutes or so during the day (the birds were under more or less frequent observation from 9 A.M. to 5 P.M.), ceasing only at feeding time (at 2 P.M.). As the summer passed, the displays became less frequent in the afternoon and gradually became largely restricted to the morning hours.

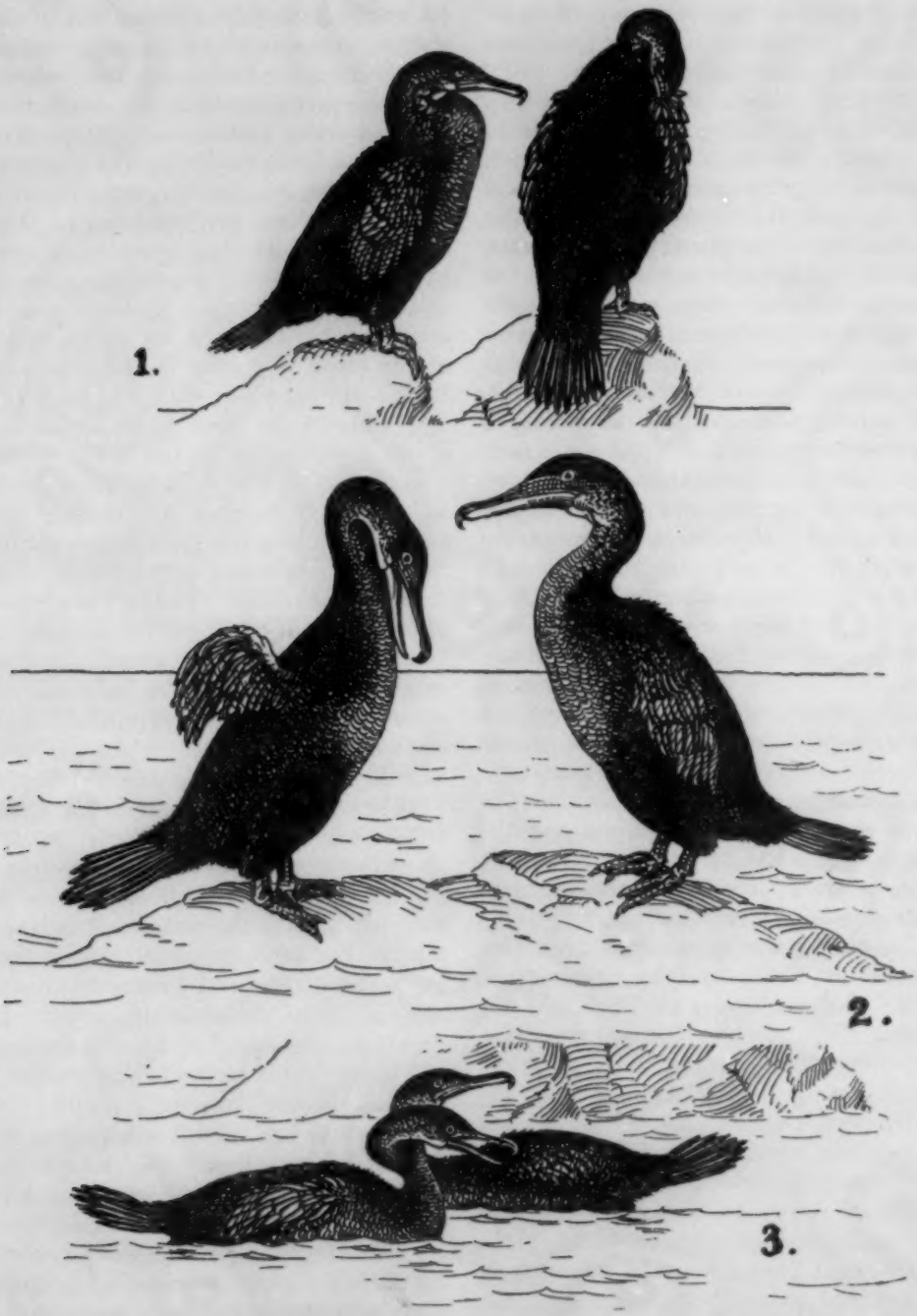
The accompanying sketches, drawn by Mr. Benson B. Moore from observations in the National Zoological Park, and the photographs taken by the senior author, illustrate the following description of the courtship performance. It may be stated at the outset that during all the movements, the breasts of the birds are continually throbbing rapidly. Sketch number 1 shows the sleeping female and the male aroused and about to begin courtship. The latter then attempts to waken and attract the attention of the hen by walking around her with a slow and rather heavy tread. His wings are raised, his neck arched, as shown in sketch number 2, and he utters the typical harsh, guttural, croaking call of the species. This usually succeeds in wakening the female. Both birds then take to the water and spin about in a small circle facing toward each other. They often separate a little, widening the diameter of the circle, but quickly come together again, as in the upper photograph. During this time both birds continually utter their low, somewhat quivering, guttural calls. If they happen to come near a stick or other object in the water, either of the birds may seize it and then continue spinning about with it in its bill.

Gradually the birds come closer and closer together, as in the lower photograph, and finally entwine their necks as in sketch number 3. During this stage, which may last for a couple revolutions of the spinning performance, their cries become milder. The pair sometimes circle about in the pond for as much as two minutes, then part, swimming separately for a short while, only to join again with louder and apparently more excited cries, when the whole performance is gone through again.

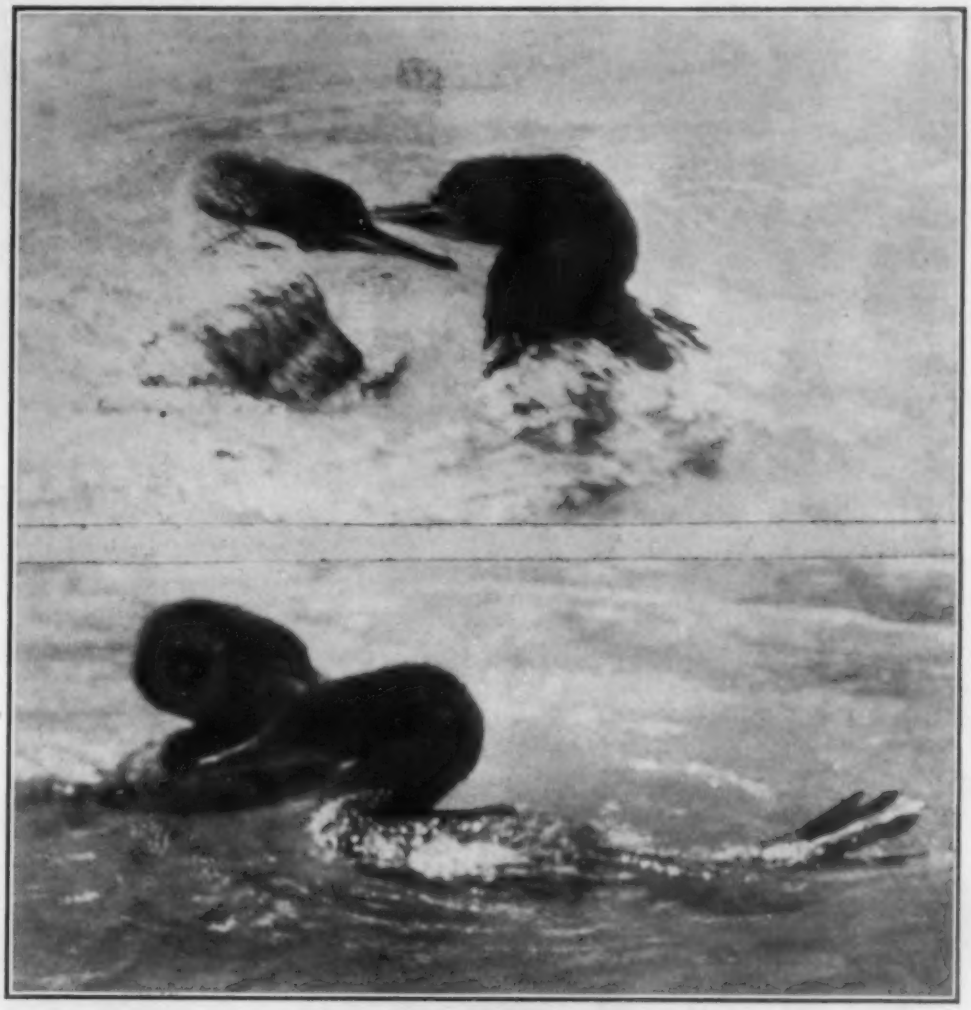
This courtship behavior is sometimes followed by attempts at copulation. No attempts were made except after such display posturing. Intercourse is attempted both in the water and on land, but, as far as our limited observations go, more often in the water. In this respect, as in the courtship itself, this flightless species differs from the species of *Phalacrocorax* written on by Portielje[2] and by Lewis.[3] The male would climb easily on the hen, almost submerging her, and attempt coitus. The female was always passive in our observations, showing no resistance to the male. Occasionally the female would swim to shore immediately after the spinning performance, whereupon the male would follow closely in her wake and attempt copula-

[2] "Ardea," pp. 107–123, 1927.

[3] "*Natural History Double-crested Cormorant*," pp. 23–27, 1929.



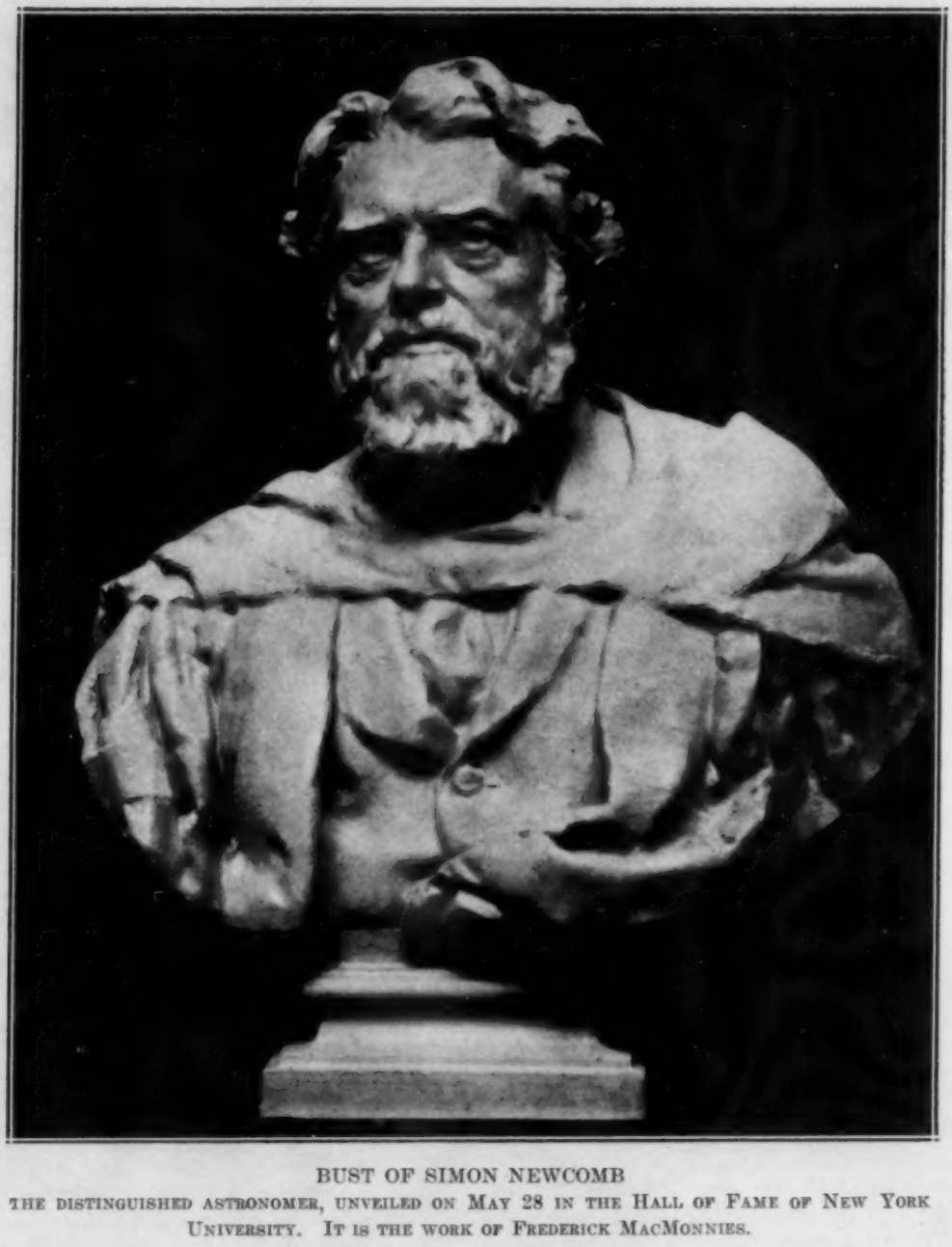
THE COURTSHIP OF THE CORMORANT



COURTSHIP IN THE WATER

tion on shore. He would attempt to place his right foot on her back, at which she would crouch as if it had been a definite, prearranged signal, and allow him to mount her. Copulation was observed only a few times, although the courtship display was indulged in day after day for many months. It undoubtedly took place numbers of other times but went unseen. The birds made no attempt to build a nest from the ample supply of straw and twigs given them, and no eggs were laid.

On the whole, the female appeared to make advances to the opposite sex in the same manner, frequency and intensity as the male. The two sexes could be distinguished by the heavier, thicker neck of the male. At times the birds fought with each other, but the scraps were of short duration and appeared to have no lasting effects.



BUST OF SIMON NEWCOMB

THE DISTINGUISHED ASTRONOMER, UNVEILED ON MAY 28 IN THE HALL OF FAME OF NEW YORK UNIVERSITY. IT IS THE WORK OF FREDERICK MACMONNIES.

THE PROGRESS OF SCIENCE

BUST OF SIMON NEWCOMB IN THE HALL OF FAME

DISTINGUISHED American astronomers honored the memory of Simon Newcomb at ceremonies in the Hall of Fame on the campus of New York University at the end of May. A bronze bust of Newcomb, first astronomer to be elected to the Hall of Fame, was unveiled in the section of the Colonnade dedicated to scientific men. The bust is the work of Frederick MacMonnies, American sculptor, and is the gift of Dr. Ambrose Swasey, Cleveland manufacturer of astronomical instruments and a close personal friend of Newcomb during the latter's lifetime.

Simon Newcomb achieved a distinguished place among the astronomers of his day because of the wide extent and importance of his labors, the variety of subjects of which he treated and the unity of purpose which guided him throughout. He set himself the gigantic task of building up, on an absolutely homogeneous basis, the theory and tables of the whole planetary system and labored at that project for over twenty years. The results of Newcomb's investigations have been adopted more or less completely by all countries for use in their nautical almanacs. He was also known for his work in connection with the theory of the motion of the moon, as a result of which he made important additions to celestial dynamics. He published important works on the Uranian and Neptunian systems and compiled a new catalogue of standard stars.

Dr. Newcomb was born in Wallace, Nova Scotia, on March 12, 1835. He became a resident of the United States in 1853 and graduated from Harvard University in 1858, where he studied mathematics and astronomy. In 1861 he became professor of mathematics in the United States Naval Academy and was placed in charge of the 26-inch telescope erected in Washington in 1873. In 1884 he became professor of mathematics and astronomy at the Johns Hopkins University. During his lifetime the astronomer was honored by many European universities and scientific societies. He died at Washington on July 11, 1909, and was given a military funeral, having been made a rear admiral by Act of Congress in 1906.

Presentation of the bust of Simon Newcomb was made by Professor Harlow Shapley, of Harvard College Observatory; Dr. W. W. Campbell, president emeritus of the University of California and director emeritus of the Lick Observatory, paid oral tribute to Newcomb's work. In the absence of Dr. Anita Newcomb McGee, eldest daughter of the astronomer, the bust was unveiled by her sister, Mrs. Emily Newcomb Wilson, who is registered by New York State as a consulting psychologist.

H. W.

THE HARVARD–M. I. T. RUSSIAN ECLIPSE EXPEDITION

HARVARD OBSERVATORY, in collaboration with the Massachusetts Institute of Technology, has sent a joint expedition to Soviet Russia to observe the total eclipse of the sun on June 19, which will not be visible from the western hemisphere. The belt of totality, which is about seventy-five miles wide, starts in the Mediterranean and then swings northeastward across Greece and the Black Sea. The well-known Siberian cities, Omsk and Tomsk, lie close to the central line. On the eastern end the track crosses Manchuria and northern Japan, ending at some point well out in the Pacific Ocean.

The Harvard-Technology group accepted the invitation of Dr. Boris P. Gerasimovic, formerly an associate at Harvard Observatory and now director of Poulkova Observatory at Leningrad, to join one of the Russian eclipse parties. The site finally chosen is near the town of Ak-Bulak, in the southern Ural Mountains, north of the Caspian Sea. The nearest large city is Orenburg, about seventy miles to the north. While Tomsk is a more favorable location, in certain respects, since the sun is higher in the sky, the collected weather reports indicate that the chances for clear weather are appreciably greater at Ak-Bulak, where totality occurs at 8:00 A. M., local time, with the sun 36 degrees above the horizon.

Dr. Donald H. Menzel, of the Harvard Observatory, is in charge of the expedition and is assisted by Dr. Joseph C. Boyce, of the Massachusetts Institute of Technology. Henry Hemmendinger, graduate student at Harvard, and a considerable group of technical assistants accompanied the expedition. The eclipse program is chiefly spectrographic. The observers plan to obtain spectrograms of the chromosphere and of the corona over a wide range of wave-lengths, with special emphasis on the infra-red region of the spectrum, where present knowledge is only fragmentary.

"Chromosphere" is a technical name for the outer layers of the sun. It is a sort of rarefied atmosphere that envelops the sun's shining surface. Observations

APPARATUS FOR PHOTOGRAPHING THE SPECTRUM OF THE CHROMOSPHERE

LEFT TO RIGHT: HENRY HEMMENDINGER AND DR. DONALD H. MENZEL, DIRECTOR OF THE EXPEDITION. INSIDE THE SPECTROGRAPH BOX WILL BE HOUSED FOUR PLANE GRATINGS, POLISHED METAL SURFACES RULED WITH 15,000 LINES TO THE INCH, WHICH WILL BE USED, EACH WITH A SEPARATE LENS AND CAMERA, TO PHOTOGRAPH THE CRESCENT OF THE ECLIPSED SUN AND THE CORONA.

of it are best obtained at time of eclipse, when the brilliant sun is hidden and only this atmosphere protrudes from behind the moon. There are many problems in connection with the chromosphere, such as its chemical composition, the source of its excitation and the nature of its structure. This atmosphere is not uniform and appears to be composed of myriads of filaments, shot geyser-like from the surface of the sun.

The solar corona lies above the chromosphere and presents additional mysteries. The chromosphere is known to consist of hydrogen, helium, calcium, iron, etc., all in the gaseous state, identified by matching colors in its spectrum with colors given off by known elements. But not a single one of the many known coronal lines has been positively identified. Astronomers at one time suspected that a new and terrestrially unknown element existed in the corona, and gave to it the name "coronium." That theory became no longer tenable when the chemists had filled all the gaps in the table of elements. Scientists now believe that coronium is some well-known substance, masquerading with the help of the peculiar conditions that exist in the corona. A couple of years ago Drs. Menzel and Boyce provisionally suggested that oxygen might be responsible, but additional data are required to settle the question one way or the other. Study of the infra-red coronal spectrum may provide the answer.

J. J. R.

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences held its seventy-third annual meeting during the last week in April at its home in Washington, D. C. The academy convenes twice each year and has done so regularly, with two exceptions, since its incorporation by Congress in 1863. The annual meeting is held in April in Washington and the autumn meeting elsewhere. New members are elected only at Washington; medals for achievements in science are awarded at both the annual and the autumn meetings. At each there are public sessions for the presentation of papers on the results of original research in different fields of science; the list of papers on each program reflects in a measure the state of development of science at that time. The complete list of papers read before the academy since the Civil War affords an indication of the progress made in science during this period.

At the business meetings the academy members consider current business items and receive reports on the work done by the academy on special problems submitted by different departments of the government for solution and advice. This procedure is in keeping with the charter of the academy and with the interpretation given it by Joseph Henry in 1867 in his report as president of the academy, in which he stated: "The objects of this association are principally to advance abstract science and to examine, investigate and experiment upon subjects on which information is desired by the Government." The purposes of the academy at the time of its founding were twofold, namely, "to afford recognition to those men of science who had done original work of real importance and thereby to stimulate them and others to further endeavors; and to aid the Government in the solution of technical scientific problems having a practical bearing on the conduct of public business." These two objectives have remained unchanged to the present time and are of vital importance to the academy. Election to membership in the academy is a public recognition of original research work in science; it also implies that the

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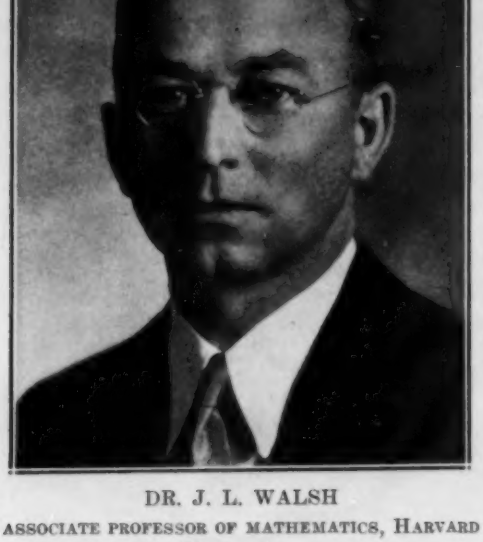

DR. ROBERT S. MULLIKEN
PROFESSOR OF PHYSICS, UNIVERSITY OF CHICAGO.

new member is competent to serve the academy effectively in the solution of problems of interest to the government. Acceptance of membership places a responsibility on the new member to aid the academy in these problems, should the need arise.

The scientific sessions of the recent annual meeting were well attended and the papers aroused interest and discussion. The distribution, among the sciences, of the 45 papers on the program was: mathematics, 3; astronomy, 4; physics, 8; engineering, 1; chemistry, 2; meteorology, 2; geology, 5; biology, 1; zoology, 2; physiology, 6; pathology, 1; medicine, 2; psychology, 4; anthropology, 1. Of these papers 31 were read by academy members and 13 by non-members. In addition 4 biographical memoirs were read by title. In the presentation of his paper each speaker made a serious effort to emphasize the essential features of his work, rather than the details, with the result that the papers, on the whole, were clear and easily understood. However, several of the papers were highly technical in character and not easily followed, except by the specialist.

The number of papers in physics indicates the continued wide-spread interest in this field. Drs. E. O. Lawrence and J. M. Cook described the successful transmutation of platinum into radioactive platinum and iridium isotopes and thence into gold through bombardment by five million volt deuterons emerging from the cyclotron. With the improved cyclotron they have succeeded in obtaining a beam of alpha particles (nuclei of helium) issuing at 11 million volts and one tenth of a microampere, thus affording a most powerful instrument and method of attack on problems in nuclear physics. Drs. R. A. Millikan, H. V. Neher and Serge Korff described tests made at high altitudes (29,000 feet) in Peru and at Manila, P. I., with automatic Neher recording cosmic ray telescopes.

The recorded great increase in ionization with height indicates that the photonic component is an important element of cosmic rays. Dr. G. R. Harrison described a method, based on new automatic instruments, for the systematic determination of wave-lengths and intensities of the spectral lines of the chemical elements. With this arrangement several million spectral lines are being measured with adequate visual control. The final results will be of great value to workers in different fields of spectroscopy. In the discussion of this paper Dr. R. W. Wood called attention to gratings which he has recently ruled on a thin aluminum film coated on a thinner film of chromium on a glass surface. These gratings are more easily ruled than speculum gratings, reflect more light in the ultra-violet and are practically free from the familiar ghosts of speculum gratings. By etching a ruled aluminum film grating on glass Dr. Wood has obtained excellent glass gratings. Dr. A. W. Hull described the results of a long series of experiments on changing direct current to alternating current by means of thyratrons with special reference to the transmission of electric power. With the apparatus now available he found no difficulty in changing currents of 200 amperes at 15,000 volts by the new method from direct to alternating current and *vice versa*. Dr. R. D. Evans spoke on new radioactivity detection technique applied to the study of radium poisoning. Dr. Simon Flexner emphasized the possibility of second attacks and reinfection in poliomyelitis. Dr. Florence R. Sabin described experiments and observations on the development of the cells of the blood and bone marrow in the rabbit. Dr. R. M. Yerkes and J. H. Elder presented the results of a long study on the sexual and reproductive cycles of the chimpanzee. This was followed by a paper by Drs. H. W. Nissen and M. P. Crawford on altruism

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DR. ORVILLE WRIGHT
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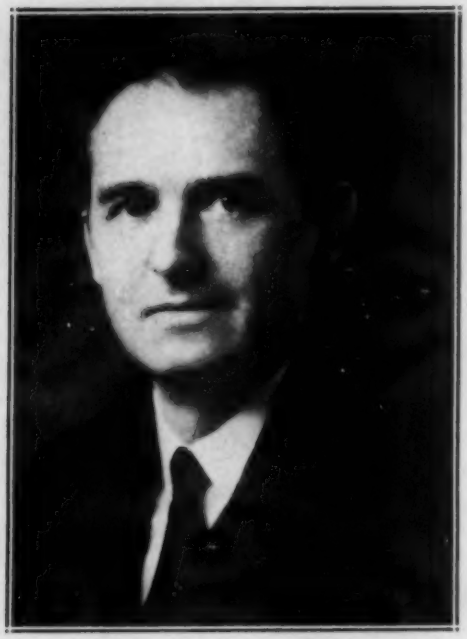

Sidney V. Webb

DR. W. F. GIAUQUE
ASSOCIATE PROFESSOR OF CHEMISTRY, UNIVERSITY OF CALIFORNIA.

and cooperation among chimpanzees, illustrated by moving pictures. Dr. Franz Boas analyzed the effects of American environment on immigrants and their descendants, as he has studied them over a period of 25 years. He has found "that the pressure exerted by social environment brings it about that the behavior of whole populations tends to be moulded by the pattern of the dominating society." Dr. C. E. Seashore reported upon the progress made in the study of the psychology of the vibrato in the rendering of music. This study has been continued over a period of years and has involved an analysis of the three kinds of vibrato, the devising of suitable instruments for the measurement of the phenomena, the gathering and analysis of the data of measurement and the discussion of the results from a psychological standpoint. Dr. W. D. Urry presented the results obtained by the application of the helium method to problems of Pre-Cambrian chronology. Dr. R. W. Wood described some new effects ob-

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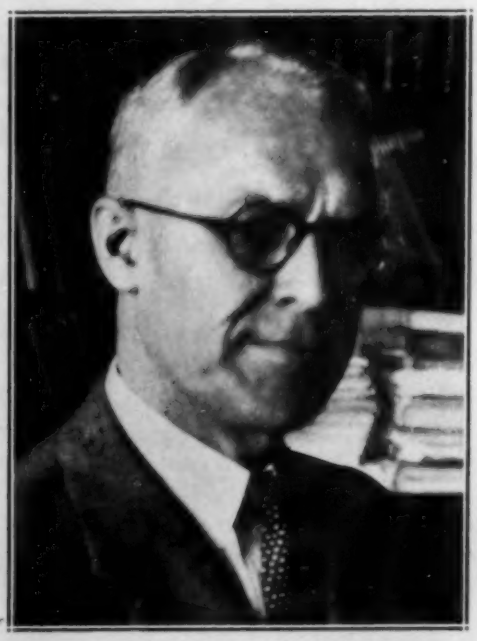

DR. ELIOT BLACKWELDER
PROFESSOR OF GEOLOGY, STANFORD UNIVERSITY.

tained with high explosives and showed unexpected behavior and flow of metals under these conditions. Dr. Linus Pauling and C. D. Coryell presented a paper on the results of magnetic measurements obtained on blood and hemoglobin solutions and indicated their significance with reference to the magnetic properties and structure of hemoglobin and related substances. Drs. E. N. Harvey, A. L. Loomis and G. Hobart described the results of measurements of electrical potentials from the human brain with special reference to the 10-cycle rhythm which appears in a person resting quietly and to the disturbances which arise when the person is disturbed.

The Monday evening public lecture was given by Dr. A. L. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, on the subject, "The Hot Springs Problem in Yellowstone Park." Drs. Day, Allen and Fenner have been at work on this

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problem for the past seven years and have studied it from many different standpoints with the result that new conceptions regarding the nature of hot springs and geysers have been developed which are of importance in connection with the metamorphism of rock masses and with the rôle played by underground and magmatic waters in modifying the materials through which they pass. The lecture was illustrated by superbly colored lantern slides and by motion pictures showing geysers in action and allied phenomena.

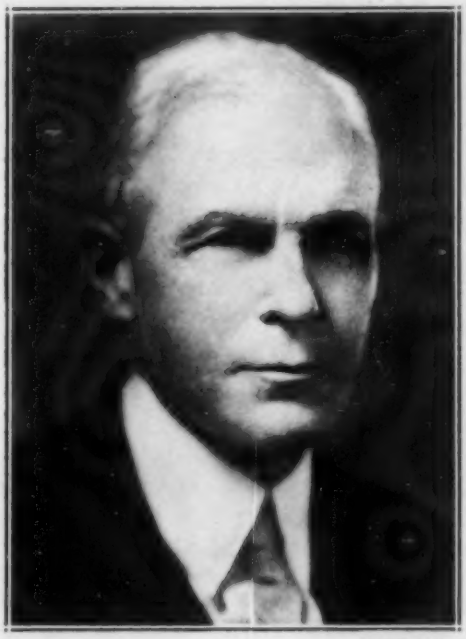
The average attendance at the sessions, in the auditorium was 350, in the lecture room 185 and at the evening lecture 300.

On Tuesday afternoon academy members were invited by Dr. R. D. W. Connor, archivist of the United States, to visit and inspect the new Archives Building of the government. The 50 members and guests who accepted the invitation were shown over the building. The facilities for receiving, cleaning, storing, filing and making accessible valuable documents were demonstrated, and the purposes of the project were explained in detail. The visit was extremely interesting and was much appreciated by the visitors.

At the annual dinner on Tuesday, President Lillie delivered, at the request of the committee on arrangements, a brief address on the status of the academy and on its accomplishments during the past year. The concluding paragraph of his address emphasizes the relation of the academy to research work in science:

> The Academy remains firmly founded on the bed-rock of scientific research, and serene in confidence in orderly thought, whether for the understanding or control of the processes in nature and in man. If any change of attitude is to be noted, it is an increased state of consciousness of public and social responsibility, which developed rapidly under the stress of the great war, and of these recent times of economic depression, stimulated by an awakened public con-

fidence and interest in science. There is no present danger, in our country at least, that scientific discovery and thought should be underestimated or suppressed; this condition should heighten our sense of responsibility to see that its power and authority are not exaggerated. The true friends of science recognize that limitations are set in nature and in the mind itself to scientific progress. We can not predict its rate, direction or extent for any considerable period of time. Yet I think that experience should give us confidence to claim that the conquering spirit of science is one of the strongest components of ideal social processes; and always will be.



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DR. WARREN H. LEWIS
DEPARTMENT OF EMBRYOLOGY, CARNEGIE INSTITUTION OF WASHINGTON AT JOHNS HOPKINS UNIVERSITY.

This was followed by the presentation of two medals: The Agassiz Medal for Oceanography, awarded to T. Wayland Vaughan, of the Scripps Institution of the University of California, La Jolla, in recognition of his investigations of corals, foraminifera and submarine deposits, and for his leadership in developing oceanographic activities on the

DR. CLARK L. HULL
PROFESSOR OF PSYCHOLOGY, YALE UNIVERSITY.

Science Service

DR. A. V. KIDDER
CHAIRMAN OF THE DIVISION OF HISTORICAL RESEARCH, CARNEGIE INSTITUTION OF WASHINGTON.

Pacific Coast of North America. The presentation address was made by Dr. Henry B. Bigelow, who was chairman of the committee which recommended the award at the last annual meeting. The Public Welfare Medal of the Marcellus Hartley Fund, awarded to Dr. F. F. Russell, formerly director of the International Health Division of the Rockefeller Foundation and at present lecturer in preventive medicine and hygiene and epidemiology at Harvard University, in recognition of his work on the etiology of yellow fever and studies of epidemic areas. The presentation address was made by Dr. Max Mason, president of the Rockefeller Foundation.

At the business session Dr. Arthur Keith, geologist of the United States Geological Survey, was reelected treasurer for a period of four years; Dr. Simon Flexner, of the Rockefeller Institute for Medical Research, and Dean J. B. Whitehead, of the Johns Hopkins University, were elected to the council for a period of three years. Fifteen men, whose portraits are here reproduced, were elected to membership in the academy.

The present membership of the academy is 293, with a membership limit of 300; there are 41 foreign associates, with a limit of 50. At the annual meeting 117 members and one foreign associate were in attendance.

The autumn meeting of the academy will be held this year on November 16, 17 and 18 at the University of Chicago.

F. E. WRIGHT,
Home Secretary

THE AMERICAN CHEMICAL SOCIETY AT KANSAS CITY

THE ninety-first meeting of the American Chemical Society was held from April 13 to 17 in Kansas City, under the presidency of Professor Edward Bartow. The two thousand visitors included representatives of Great Britain, the Netherlands and Switzerland. A program of some three hundred scientific papers was supplemented by trips to local industrial and municipal plants.

Chemistry presents a picture of ever-increasing specialization. The members of the nineteen subdivisions scarcely speak one another's language. Yet a newly formed section, *Deuterium*, occasioned the liveliest interest. This is due to the fact that Professor Urey's discovery of "heavy hydrogen" was not only of profound theoretical significance, but also has proved to have far-reaching applications. For example, the biochemists can study physiological processes more accurately than ever before, through the earmarking of synthetic drugs and foodstuffs with deuterium. Investigations in the field of catalysis, of which our knowledge is all too empirical, will be expedited through the application of this powerful new tool.

Two investigators from the University of Wisconsin, Dr. N. F. Hall and T. O. Jones, reported a series of determinations from which they concluded that the distribution of deuterium on the earth's surface was 1 part in 6,500 of water.

Every reader of the press is aware of heavy hydrogen, but it is quite another matter for the invariability of oxygen to be questioned. The layman may still rest assured that in any sample of water he is likely to meet, the ratio of oxygen to hydrogen will be 16 to 1, but a variation from this ratio of a few parts per million is of the greatest concern to the scientist. The isolation of isotopes has long since ceased to be a one-man job, for Dr. F. W. Aston, of the University of Cambridge, and Dr. Malcolm Dole, of Northwestern University, have now made the startling discovery that the atomic weight of oxygen is not invariably 16. An isotope of weight 18 exists,

DR. E. R. WEIDLEIN
DIRECTOR OF THE MELLON INSTITUTE OF INDUSTRIAL RESEARCH, PITTSBURGH; PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY.

and is in greater concentration in the atmosphere than in the ocean. To account for this, the hypothesis is advanced that an interchange of oxygen atoms takes place in the stratosphere under the influence of ultra-violet light. Molecules of water composed of hydrogen and "heavy oxygen" lose the latter and acquire atoms of conventional oxygen instead.

Another new section was microchemistry, which comprises far more than the application of the microscope to chemical investigations. It is used in blood analysis, detection of new hormones, exposure of fraud, catalysis, etc. A whole new technique has been elaborated, and the tools employed consist of a balance sensitive to one millionth of a gram, micro-distilling flasks, micro-pipettes and sensitive and highly specific reagents. Of particular interest to consumers was the announcement of a new reagent, *dithizone*, used by the Food and Drug Administration for the detection of lead in fruits.

The stimulation of agriculture through increased use of the soybean was con-

sidered important enough for a special symposium. The 1935 crop was 39 million bushels. The potential utilization has been only slightly explored, but already soybean meal is eaten by live stock and by man as well, in products such as bread, candy, macaroni, seasoning powders and sauces. The paint and soap industries have found the oil (a by-product of the meal) to be capable of wide application.

Vitamin research is proceeding apace, as would be expected. Of special interest was the report of the staff of the Oklahoma Agricultural and Mechanical College that cod liver oil contains vital nutritive constituents other than vitamins A and D. The authors were conservative in their statements, but if further work substantiates their present results, it will demonstrate what has long been suspected, namely, that the so-called vitamin pills can not be regarded as a substitute for cod liver oil.

Other work in the field of nutritive and medicinal chemistry included studies of goiter-preventing foods; aluminum hydroxide in removing fluorides from water; the rôles played by iron and copper in combatting anemia; and the rôle of sulfur (in combination, as the amino-acid cystine) in preventing arthritis.

Increased utilization of coal before our oil reserves have been depleted was forecast by the work of Dr. R. S. Asbury, of the Carnegie Institute of Technology. Coal can be liquefied and used in place of oil by combining it with hydrogen. In order to hydrogenate coal, it must be in solution and, surprisingly enough, Dr. Asbury succeeded in dissolving 85 per cent. of a sample of bituminous coal in tetralin, a cheap solvent derived from naphthalene. Elucidation of the chemical composition of coal may be expected as a result of pushing this work to its logical conclusion.

The increasing complexity of chemistry makes it imperative to choose the subject-matter of a high-school course skilfully. In the section of chemical education, it was suggested that inasmuch as the great majority of high-school chemistry students will never open another text-book, they should not be enmeshed in the intricacies of atomic structure, but should instead be taught the practical applications of the subject. For example, they should be taught how simple are the mixtures used in making cosmetics, dentifrices and proprietary medicines. They should learn to regard all pseudo-scientific advertising with complete skepticism. In that way the purveyors of fraudulent preparations will disappear without the necessity of a law with teeth in it.

THOMAS B. GRAVE

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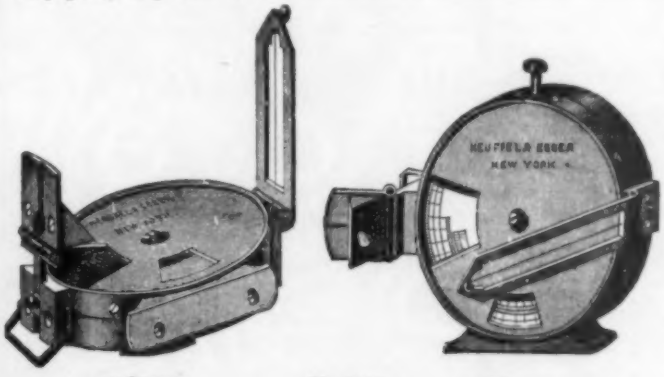

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